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KENTUCKY GEOLOGICAL SURVEY

J. B. HOEING, STATE GEOLOGIST

IN CO-OPERATION WITH

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

MISSISSIPPIAN FORMATIONS OF WESTERN KENTUCKY

Butts, Charles, 1873-

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DESCRIPTIONS AND CORRELATION OF THE MISSISSIPPIAN FORMATIONS OF WESTERN KENTUCKY

BY

CHAS. BUTTS.

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INTRODUCTION.

The investigation, the results of which are set forth in this report, was undertaken with the object of identifying the stratigraphic units of the Mississippian series in Kentucky from Louisville to the west end of the State and of acquiring facts on which to base the correlation of these units with those of the standard Mississippian section of the Mississippi Valley. The objects sought were necessary, first, for the simplification of stratigraphic nomenclature, and second, for the extension of knowledge regarding the depositional history of the different stratigraphic units. The positive identification of a formation as the same from place to place or the correct correlation of a formation in detached areas of outcrops permits, with obvious advantages in mental economy, the use everywhere of the same name for the same formation instead of two or more local names. Further, identification of formations from place to place makes possible the determination of their geographic limits as well as the changes in their lithologic character and organic contents in the different areas, and from these facts much can be inferred concerning the geographic environment of a formation at the time of its origin. The Mississippian formations of the Mississippi Valley having been mainly accumulated as sediments in marine water, it is obvious that the sea in which a given formation originated extended at least as far as the existing formation, and where the latter is now absent land may have existed contemporaneously with the sea. Thus it is possible to make out approximately the ancient distribution of land and water. Furthermore, if the same stratigraphic unit, that is, the body of rock laid down on the sea bottom contemporaneously throughout its extent, is in one area a pure limestone and in another area a shale, it is evident that the first area received but little earthy sediment from the land while the second did receive such material. So we infer that the area of limestone accumulation was at considerable distance from land where the

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water remained free from muddy sediment or was protected from such sediment by some other means as by a bar, and infer that the area of shale accumulation was nearer shore perhaps off the mouth of a river which discharged muddy sediment from time to time as rivers do in the present age. Such are some of the problems on which studies such as those leading up to this report throw light.

This report has been prepared jointly by the Kentucky Geological Survey and the United States Geological Survey. To a certain extent also it is based upon co-operative work done in southern Illinois by the Illinois Geological Survey and the United States Geological Survey.

Special acknowledgment is due to E. O. Ulrich, Stuart Weller, and Geo. H. Girty, who, through their wide knowledge of the Mississippian stratigraphy and fossils, have given the writer invaluable aid in the matter of discriminating the various formations.

STRATIGRAPHY.

GENERAL RELATIONS.—The area covered by this investigation is a broad, roughly semicircular belt bordering the western Kentucky coal field on the west, south, and east, beginning in southern Illinois between Paducah, Ky., and Shawneetown, Ill., and extending by way of Crittenden, Livingston, Caldwell, Christian, Todd, Logan, Warren, Hart, Hardin, Breckinridge, Meade, Bullitt, and Jefferson counties, Ky., to Ohio River between Louisville and Cloverport. (See index map, Plate 1.) Within this belt strata of limestone predominate, but in the upper part of the limestone mass there are several strata of sandstone interbedded with limestone and in the extreme eastern part of the belt in Jefferson, Bullitt, and Meade counties the lowest Mississippian rocks are sandstone and shale. The general sequence and equivalence of formations in both the eastern and western ends of the belt are exhibited in the two generalized sections on the right of Plate 2. The different stratigraphic units, or briefly, formations, will be described in ascending order which is the chrono-

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logical order of their deposition. The lowest strata were first deposited and so on in upward succession.

The rocks in this belt dip at all points toward the western Kentucky coal field which lies in the center of the southern end of the broad syncline holding also the great Illinois and Indiana coal fields. This belt of country is the only area of Mississippian rocks forming a practicable connection between the Mississippian of the west side of the Cincinnati anticline and the Appalachian region farther east and the Mississippian rocks of the type locality of Mississippi Valley.

CHATTANOOGA SHALE.

Underlying the Osage group of the Mississippian rocks in central Kentucky and southern Illinois is the well known black shale variously known in different areas as Chattanooga shale, Ohio shale, and New Albany shale, which, being a persistent and lithologically identical formation throughout a large area, is a reliable stratigraphic datum plane from which the description and comparison of the Mississippian formations can proceed. At Louisville the formation (in that region known as the New Albany shale) is a slaty, densely black, and fissile shale with here and there a thin layer of green shale and a few thin layers of wave marked, fossiliferous, calcareous sandstone. Its thickness is 100 feet. In Hardin County, Ill., just southeast of Hicks, this shale is exposed in a belt surrounding the center of a structural dome exposing a central core of Devonian limestone of Onondaga age. It is there 300 to 400 feet thick and so far as observed a black fissile shale through its entire thickness. The black shale has been encountered in a deep well at Stephensport in Breckinridge County and in one near Meredith in Grayson County, as shown in section Nos. 16 and 27 of the chart, Plate No. 3.

Up to comparatively recent times the Chattanooga shale had been universally classed as Upper Devonian. It is now maintained by some geologists, notably by E. O. Ulrich, to be in its upper and greater part of basal Mississippian (Kinderhook) age. A discussion of the question of the age of the black shale is not appropriate for this paper, so the matter will be passed

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with the statement of the writer's opinion that it is mainly Devonian.

OSAGE GROUP.

As shown by the generalized section on the right of Plate 2, the Osage group, on its eastern outcrop in Jefferson and Bullitt counties, Ky., in other counties southward from Bullitt, probably in Meade and the eastern part of Breckinridge County, Ky., and in the adjacent parts of Indiana is composed of the following shale or sandstone formations: New Providence shale, Kenwood sandstone, Rosewood shale, and Holtsclaw sandstone. These formations constitute the old "Knobstone" group, "Knobstone" now being superseded by the geographic name Osage from Osage River in western Missouri, which drains a large area of strata of this age. Westward from the counties named the Osage group changes from shale and sandstone to cherty limestone. This change has apparently affected a considerable thickness of the Rosewood shale at Rock Haven, Ky., where 20 feet or more of very cherty limestone of typical Osage character appears near river level (See section No. 35 of the chart, Plate No. 3.) At Stephensport, Ky., 45 miles west of Louisville, the change may be complete, for at that point a deep well which penetrated to the New Albany shale encountered, according to report, only limestone below the first 100 feet. No. 27 of the chart, Plate 3, is a section of the strata pierced by the well. It is possible that the report of all limestone is erroneous for the identification of the kind of rock penetrated in deep wells is often wrong.

The Osage rocks are brought to outcrop from beneath the western Kentucky coal basin on an anticlinal dome in Hardin County, Ill., 100 miles nearly west of Stephensport. There they are cherty limestone as they are also in the Mississippi Valley.

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NEW PROVIDENCE SHALE.*

The New Providence shale, named from New Providence, Ind., is a soft clay shale of greenish or bluish color. The shale weathers to clay. Generally in the upper half there are present numerous iron carbonate nodules, and in places, as Button Mould Knob, 12 miles south of Louisville, are thin ferruginous limestone layers with many fossils—Brachiopods, Bryozoa, and Crinoids scattered through the middle 50 feet. In places where there are no limestones the formation is nonfossiliferous. A notable example of this is the locality of Kenwood Hill, 5 miles south of Louisville. At the south end of this hill nearly the full thickness of the formation is exposed and the conditions for exposing and liberating fossils are especially favorable, yet not a fossil is to be found; while one-half mile north, on the west side of the hill where thin limestone layers are present, fossils are abundant. The rich fauna, especially of crinoids, described from the Osage ("Knobstone") group of Kentucky, has been mostly obtained from the New Providence shale. Button Mould Knob is the most famous locality for these fossils. Except for 20 feet or so at the top, the knob is entirely in the New Providence shale. The old shale pit at Hunters Trace, visible from the Illinois Central Railroad, is in the New Providence shale. The thickness of the New Providence is about 150 feet in the knobs south of Louisville. Below is a list of the fossils of the formation.

LIST OF FOSSILS FROM THE NEW PROVIDENCE SHALE OF KENTUCKY AND INDIANA.

Sponge spicules?

Corals.

- Amplexus fragilis. White and St. John.
- Amplexus sp.
- Amplexus? sp.
- Cladochonus aff. gracilis. Keyes.
- Cladochonus aff. longi. Rowley.
- Cyathaxonia arcuata. Weller.
- Cyathaxonia cynodon. Rafinesque and Clifford.
- Cyathaxonia sp.

*Borden, W. W., Ind. Dept. Geol. and Nat. Res., 5th Ann. Rept., p. 161, 1874.

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Cyathaxonia? n. sp.
Favosites valmeyerensis? Weller.
Monilipora amplexa. Rowley.
Palæacis cavernosa. Miller.
Palæacis? sp.
Striatopora aff. carbonaria. White.
Trochophyllum verneuilianum. Milne-Edwards and Haime.
Triplophyllum centralis. (Milne-Edwards and Haime.)
Triplophyllum cliffordana. (Milne-Edwards and Haime.)
Triplophyllum? declinis. (Miller.)
Triplophyllum sp.

Crinoids.*

Actinocrinus 1 sp.?
Agaricocrinus 2 sp.
*Amphoracrinus.
Barycrinus 3 sp.
*Cactocrinus 1 sp.
Catillocrinus tennesseeae. Shumard.
Cyathocrinus 6 sp.
Eretmocrinus yandelli.
Euryocrinus 1 sp.
*Forbesiocrinus, nobilis type.
*Gilbertsocrinus cf. tenuiradiatus. Meek and Worthen.
Halysiocrinus perplexus. Shumard.
Halysiocrinus sp.
Megistocrinus.
*Mespilocrinus 2 sp.
*Metichthyocrinus tiaraeformis. Hall.
*Metichthyocrinus clarkensis. Miller and Gurley.
Orophocrinus cf. stelliformis. Owen and Shumard.
*Platycrinus americanus. Owen and Shumard, or yandelli Owen and Shumard. discoid form.
Platycrinus burlingtonensis? Owen and Shumard. } Elongate or erect forms.
Platycrinus cf. granosus.
Platycrinus planus. Owen and Shumard.
Platycrinus sculptus. Hall.
Platycrinus sp.?
Platycrinus verrucosus. White.
*Platycrinus cf. yandelli. Owen and Shumard. discoid form.
Scaphiocrinus 1 sp.
Schizoblastus sp.
Schizoblastus decussata.
Stemmatocrinus trautscholdi. Wachsmuth and Springer.
Synbathocrinus angularis. Miller and Gurley.

*List of crinoids quoted from Springer. Springer, Frank, The Crinoid Fauna of the Knobstone formation: Proc. U. S. Nat. Mus., vol. 41, pp. 175-206, 1911.

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Synbathocrinus robustus. Shumard.
Taxocrinus.
Wachsmuthicrinus 2 sp.

Bryozoa.

Chainodictyon? sp.
Cystodictya americana. Ulrich.
Cystodictya lineata. Ulrich.
Cystodictya pustulosa. Ulrich.
Fenestella compressa. Ulrich.
Fenestella regalis. Ulrich.
Fenestella triserialis. Ulrich.
Fenestella sp.
Fistulipora sp.
Lioclema punctatum? Hall.
Meekopora? aperta. Ulrich.
Polypora sp.
Ptilopora cylindracea. Ulrich.
Rhombopora angustata. Ulrich.
Rhombopora elegantula. Ulrich.
Rhombopora incrassata. Ulrich.
Rhombopora sp.
Stenopora.
Streblotrypa major. Ulrich.
Thamniscus divaricans. Ulrich.
Thamniscus sculptilis. Ulrich.

Brachiopods.

Brachythyris suborbicularis. Hall.
Chonetes planumbonus. Meek and Worthen. var.
Chonetes shumardianus. de Koninck.
Cliothyridina aff. glenparkensis. Weller.
Productus semireticulatus. Martin.
Ptychospira sexplicata. White and Whitfield.
Pustula n. sp.
Pustula punctata. Martin.
Rhipidomella oweni. Hall and Clarke.
Schuchertella aff. lens. White.
Spirifer aff. floydensis. Weller.
Spirifer aff. logani. Hall.
Spirifer aff. moorefieldanus. Girty.
Spirifer aff. vernonensis. Swallow.
Spiriferina subelliptica. McChesney.

Pelecypods.

Paleoneilo sp.
Posidoniella? sp.

Gastropods.

Platyceras sp.

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Cephalopods.

Goniatites sp.

Trilobites.

Brachymetopus sp.

Griffithides sp.

Ostracoda.

The more common or the characteristic fossils of the New Providence are shown on Plate 4.

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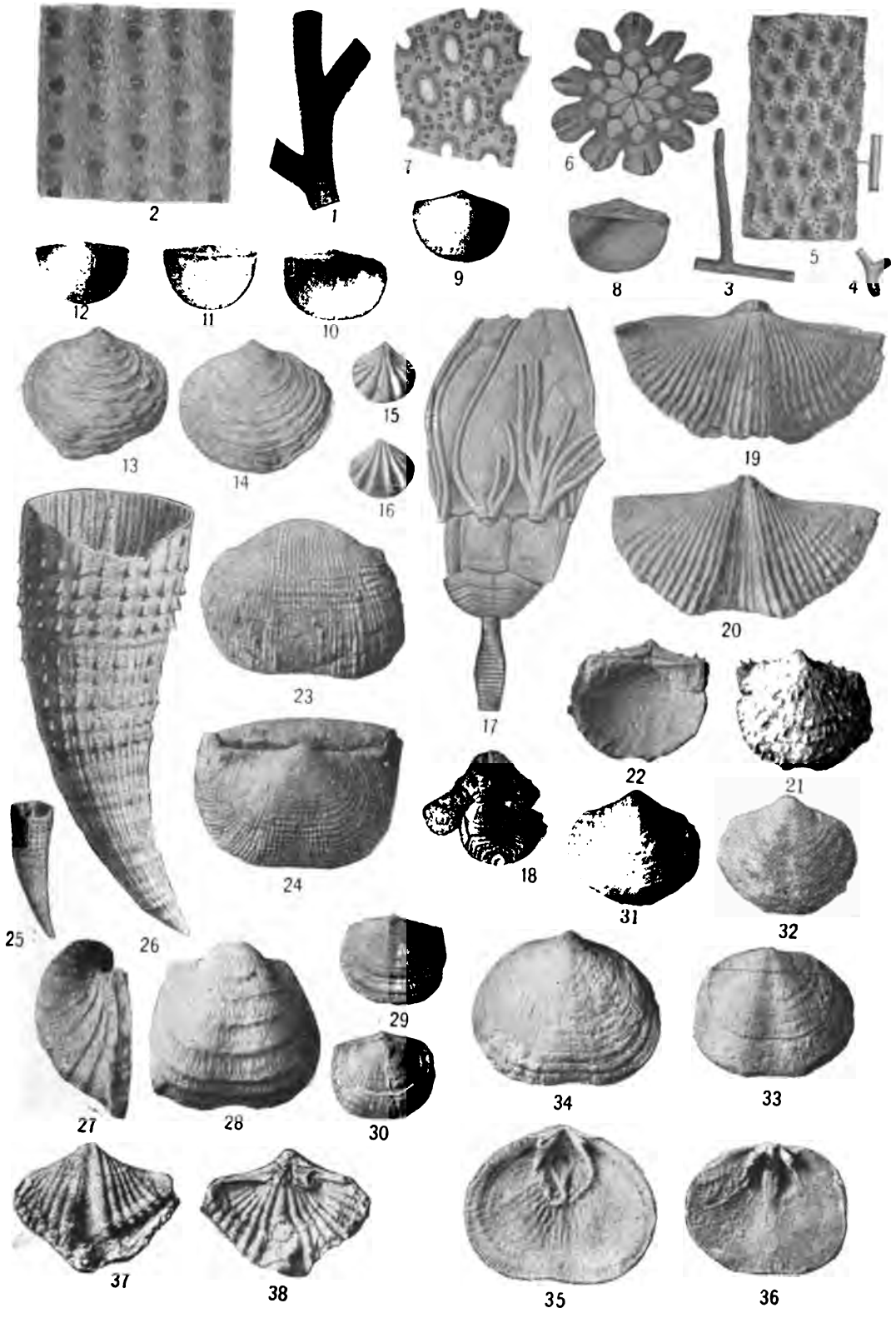

PLATE 4.
Fossils of the New Providence Shale.

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FOSSILS OF THE NEW PROVIDENCE SHALE.
Plate 4.

1-2 Cystodictya lineata. Ulrich. 1, view of a part of a branch natural size; 2, portion of the same enlarged, showing the shape and arrangement of the cell mouths and the linear ridges separating them. Common bryozoan of the Osage and Meramec groups, New Providence shale to Spergen limestone.

3-7 Rhombopora incrassata. Ulrich. After Ulrich. 3 and 4, fragments natural size and enlarged 12 times; 6, transverse section; 7, tangential section.

8-9 Chonetes planumbona. Meek and Worthen. After Weller. 8, brachial; 9, pedicle valve. New Providence shale. Common at Button Mould Knob and Kenwood Hill.

10-12 Chonetes shumardanus. de Koninck. After Weller. 10, interior of a pedicle valve, such specimens common; 11, brachial; and 12, pedicle valve. New Providence shale to Holtsclaw sandstone. Fairly abundant at Kenwood Hill and Button Mould Knob.

13-14 Athyris hannibalensis. (Swallow.) After Weller. 13, brachial; 14, pedicle view. New Providence shale only.

15-16 Ptychospira sexpeicata. (White and Whitfield.) 15, brachial; 16, pedicle valve. New Providence shale only. After Weller.

17-18 Platycrinus sculptus. Hall. After Wachsmuth and Springer. This is a fine example of a crinoid "Stone lily," the stem of which furnishes the "buttons" so abundant at Button Mould Knob and Kenwood Hill. This specimen was not obtained at Button Mould Knob but detached plates of the basal parts are common there showing that it lived in the sea covering this region in New Providence time.

19-20 Spirifer vernonensis. Swallow. After Weller. 19, brachial; 20, pedicle valve. This or a very similar form occurs in the New Providence shale at Kenwood Hill and Button Mould Knob.

21-22 Strophalosia cymbula. Hall and Clark. After Weller. 21, pedicle; 22, brachial valve. New Providence shale.

23-24 Productus fernglenensis. Weller. After Weller. 23, pedicle; 24, cardinal view of a valve, showing the reticulated ornamentation. This or a very similar form present in the New Providence of this region and listed as Productus semireticulatus.

25-26 Cyathaxonia cynodon. Rafinesque and Clifford. After Edwards and Haime. Common cup coral of the New Providence shale at Button Mould Knob and elsewhere. The slender cone in the center of the cup is a characteristic feature.

27-28 Echinoconchus (Pustula) alternatus. (Norwood and Pratten.) After Weller. 27, profile; 28, pedicle view. This or a similar

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form occurs in the New Providence shale and is listed as Pustula punctata.

29-30 Schuchertella lens. (White.) After Weller. 1, pedicle; 2, brachial valve. New Providence shale.

31-32 Chothyridina glenparkensis. Weller. After Weller. 31, brachial; 32, pedicle view. This or a similar form occurs in the New Providence shale.

33-36 Rhipodomella oweni. Hall and Clarke. After Weller. 33, brachial; 34, pedicle valve; 35, interior of pedicle; 36, interior of brachial valve. New Providence shale only. Abundant at Button Mould Knob and Kenwood Hill.

37-38 Spiriferina subelliptica. McChesney. After Weller. 37, pedicle; 38, brachial valve. New Providence shale. Common at Button Mould Knob and Kenwood Hill. Specimens doubtfully referred to this species occur in the Rosewood shale and Holtsclaw sandstone.

According to Girty,* this fauna, with the exception of some of the crinoids cannot be satisfactorily correlated with any Mississippian fauna in the Mississippi Valley or farther west. Excepting the crinoids and possibly some of the bryozoa, the fauna is unique. According to Springer† at least 10 species or genera of the New Providence crinoids are unknown in rocks younger than the Burlington limestone. On the other hand, the formations immediately above the New Providence shale are on the basis of their faunas clearly correlatable with the typical Keokuk limestone which overlies the Burlington limestone. Therefore, on the evidence of its crinoids and of its stratigraphic position below rocks of well determined Keokuk age the New Providence is correlated with the Burlington limestone of the standard Mississippian section of the Mississippi Valley.

KENWOOD SANDSTONE.

The Kenwood sandstone, named from Kenwood Hill 5 miles south of Louisville,‡ is composed of alternating layers of sandy shale and of fine-grained greenish sandstone in layers up to 10 feet thick. Generally the sand-

*Girty, Geo. H., Geology of Jefferson County, Ky. Kentucky Geological Survey, Ser. 4, Vol. 3, pt. 2, pp. 144-147, 1915.

†Springer, Frank, The Crinoid Fauna of the Knobstone formation: Proc. U. S. Nat. Mus., Vol. 41, pp. 175-208, 1911.

‡Butts, Charles, Geology of Jefferson County, Ky. Kentucky Geol. Survey, p. 148, 1915.

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stone layers are only a few inches thick. The formation is 40 feet thick; it is present throughout the "Knobs" of southern Indiana and of Jefferson and Bullitt counties, Ky. The formation is sparsely fossiliferous, a few specimens of *Productus wortheni* only having been obtained from it.

The Productus not being known elsewhere beneath the Keokuk limestone, the Kenwood is regarded as representing a Keokuk and probably a lower Keokuk horizon.

ROSEWOOD SHALE.

The name Rosewood is from Rosewood, Ind., on Ohio River, 15 miles southwest of Louisville.† The Rosewood shale is a hard bluish shale 190 feet thick. It is siliceous and does not split smoothly. Distributed through it quite generally are peculiar, whitish, curly markings about one-sixteenth of an inch broad and one-half inch or more long. These markings have not been noticed in any other rocks and seem to be characteristic of the Rosewood shale. They are present in similar shale at Ridgetop, Tenn., and evidently have a rather wide geographic distribution. There is locally a sandstone layer 5 feet or so thick, 30 feet below the top of the formation and thin limestone lenses 70 feet below the top, which appears to be a widely extended limestone horizon. On the Louisville & Nashville Railroad about 1 mile south of Colesburg, Ky., is 10 feet of thick bedded crinoidal limestone, and at Rock Haven on Ohio River is a bed of cherty limestone at least 20 feet thick, apparently at this horizon. The westward increase in the relative proportion of limestone is clearly exhibited in these scattered exposures. This increase goes on until the eastern shaly and sandy facies of the Osage group has been transformed into the typical western or limestone facies. This shaly facies extends also southwestward into the Central Basin of Tennessee, outcropping along the northern margin of the Nashville dome to western Tennessee, where it passes beneath the cover of younger rocks.

The Rosewood shale is decidedly more fossiliferous than the Kenwood sandstone. The species occurring are listed below:

†Butts, Charles, Loc. Cit., p. 150.

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FOSSILS OF THE ROSEWOOD SHALE.

Fucoid? whitish markings like worm trails. Abundant.

Corals.

- Amplexus fragilis. White and St. John.
- Cladochonus aff. longi. (Rowley.)
- Triplophyllum sp.

Crinoid (Blastoid.)

Bryozoa.

- Cystodictya sp.
- Fenestella several species.
- Hemitrypa sp.
- Pinnatopora sp.
- Rhombopora several species.

Brachiopods.

- Brachythyris suborbicularis. (Hall.)
- Chonetes shumardanus. de Koninck.
- Chonetes sp.
- Cliothyridina parvirostris. (Meek and Worthen.)
- Cyrtina aff. burlingtonensis. Rowley.
- Dielasma sp.
- Productus aff. arcuatus. Hall.
- Productus crawfordsvillensis? Weller.
- Productus wortheni? Hall.
- Productus ovatus. Hall.
- Reticularia pseudolineata. (Hall.)
- Rhynchopora beecheri? Greger.
- Schuchertella (aff.?) chemungensis. (Conrad.)
- Spirifer floydensis. Weller.
- Spirifer rostellatus. Hall.
- Spiriferina subelliptica? McChesney.

Pelecypods.

- Conocardium sp. a.
- Conocardium sp. b.
- Crenipecten? sp.
- Cypricardinia aff. scitula. Herrick.
- Leda? sp.
- Paleoneilo aff. bedfordensis. Meek.

Gastropods.

- Bembexia n. sp.
- Bucanopsis? sp.
- Oxydiscus sp.
- Platyceras sp.

Cephalopods.

- Orthoceras sp.

Trilobites.

- Phillipsia? sp.
- Brachymetopus elegans? Girty.

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Of the above list *Cliothyridina parvirostris, Reticularia pseudolineata* and *Spirifer rostellatus* are characteristic Keokuk forms and warrant the correlation of the Rosewood shale with some part of the Keokuk limestone. This subject is further discussed in connection with the description of the Holtsclaw sandstone which follows.

HOLTSCLAW SANDSTONE.

The Holtsclaw sandstone is named from Holtsclaw Hill 10 miles south of Louisville.* It is the top formation of the Osage ("Knobstone") group and is a rather soft, fine-grained sandstone tending to be massive in bedding. It is 20 feet or less thick in the "Knobs" region of southern Jefferson County, Ky., and on the river bluff in Indiana west of Jefferson County. In the northwestern part of Bullitt County, to the east of Kosmosdale, it is absent locally at least, the Warsaw there directly overlying the Rosewood shale.

The Holtsclaw is moderately fossiliferous, the following species having been collected:

LIST OF FOSSILS FROM THE HOLTSCLAW SANDSTONE.

Fucoid.
Corals.
- **Cladochonus aff. gracilis. Keyes.**
- **Cladochonus sp.**
- **Triplophyllum sp.**

Bryozoa.
- **Batostomella? sp.**
- **Cystodictya lineata? Ulrich.**
- **Cystodictya sp.**
- **Dichotrypa? sp.**
- **Fenestella several species.**
- **Hemitrypa sp.**
- **Lioclema sp.**
- **Polypora several species.**
- **Rhombopora? sp.**
- **Stenopora sp.**

Brachiopods.
- **Athyris lamellosa. l'Eveille.**
- **Brachythyris suborbicularis. (Hall.)**
- **Chonetes shumardanus. de Koninck.**

*Butts, Charles. Loc. Cit., p. 151.

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Chonetes sp.
Crania n. sp.
Dielasma aff. ferngleneusis. Weller.
Eumetria verneuiliana. (Hall.)
Lingulidiscina sp.
Orthotetes keokuk. (Hall.)
Productus arcuatus. Hall.
Productus crawfordsvillensis. Weller.
Productus n. sp.
Productus aff. ovatus. Hall.
Productus aff. parvus. Meek and Worthen.
Productus sp.
Productus wortheni. Hall.
Pustula alternata? (Norwood and Pratten.)
Reticularia pseudolineata. (Hall.)
Reticularia sp.
Rhynchopora beecheri. Greger.
Spirifer crawfordsvillensis. Weller.
Spirifer floydensis. Weller.
Spirifer keokuk. Hall.
Spirifer montgomeryensis. Weller.
Spirifer rostellatus. Hall.
Spirifer tenuicostatus. Hall.
Spirifernia subelliptica? McChesney.
Spirifernia sp.
Syringothyris textus. (Hall.)

Pelecypods.

Aviculipecten sp.
Conularia sp.
Cypricardinia aff. scitula. Herrick.
Myalina keokuk? Worthen.

Gastropods.

Platyceras sp.

Trilobites.

Phillipsia sp.

In this list *Orthotetes keokuk, Productus wortheni, Reticularia pseudolineata, Rhynchopora beecheri, Spirifer rostellatus, Spirifer keokuk* and *Syringothyris textus* are typical Keokuk species and there seems to be no ground for doubting the Keokuk age of the Holtsclaw. As the Kenwood sandstone below the Rosewood shale is of Keokuk age it follows that the three formations, namely, Kenwood sandstone, Rosewood shale, and Holtsclaw sandstone are collectively about equivalent to Keokuk limestone.

These fossils and others are illustrated on Plate 5.

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FOSSILS OF THE ROSEWOOD SHALE AND HOLTSCLAW SANDSTONE. ALL AFTER WELLER.

Plate 5.

1-3 Productus wortheni. Hall. 1, pedicle; 2, profile; 3, brachial view. Kenwood sandstone to Holtsclaw sandstone. Common.

4-6 Cyrtina burlingtonensis. Rowley. 4, brachial; 5, pedicle; 6, profile view. Rosewood shale.

7-9 Syringothyris textus. (Hall.) 7, brachial; 8, pedicle; and 9, profile view. Holtsclaw sandstone only.

10-11 Spirifer rostellatus. Hall. 10, brachial; 11, pedicle view. Rosewood shale and Holtsclaw sandstone only.

12 Reticularia pseudolineata. (Hall.) Pedicle valve. Rosewood shale and Holtsclaw sandstone only.

13 Brachythyris (Spirifer) suborbicularis. (Hall.) Pedicle valve. New Providence shale to Holtsclaw sandstone.

14-15 Rhynchopora beecheri. Greger. 14, pedicle; 15, brachial valve. Holtsclaw sandstone and perhaps Rosewood shale also.

16-17 Orthotetes (Derbya) keokuk. (Hall.) 16, pedicle; 17, brachial valve, both partly exfoliated showing interior markings. Holtsclaw sandstone only.

18-19 Spirifer crawfordsvillensis. Weller. 18, pedicle; 19, brachial valve. Rosewood shale and Holtsclaw sandstone.

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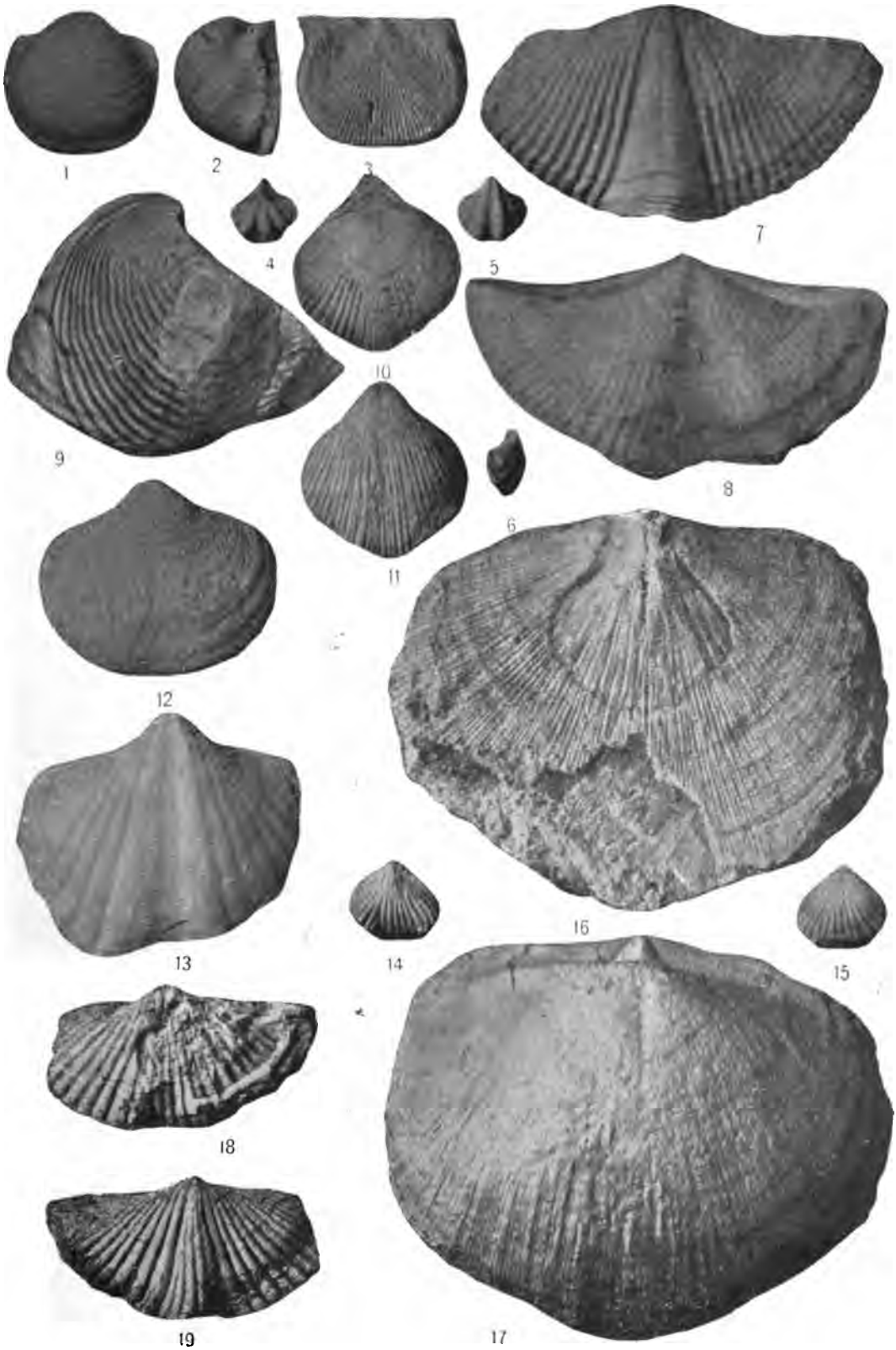

PLATE 5.

Fossils of the Rosewood shale and Holtsclaw sandstone. All after Weller.

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FORT PAYNE ("TULLAHOMA") CHERT.

In Hardin County, Ill., the rocks of Osage age directly overlie the black Chattanooga shale and are composed of a cherty limestone not divisible into formations. To this undifferentiated mass the name "Tullahoma formation" was applied by Bain* and Ulrich.† The name, which was taken from the town of Tullahoma, Tenn., was originally introduced by Safford and Killebrew‡ for rocks in Tennessee between the Chattanooga shale and the St. Louis limestone. As delimited by Safford, the main mass of the "Tullahoma formation" seems to be stratigraphically equivalent to the Fort Payne chert of Alabama, although somewhat modified lithologically. The name "Tullahoma formation" has therefore been abandoned by the United States Geological Survey in favor of the older name Fort Payne chert, from Fort Payne, DeKalb County, Ala. The transformation of the shale and sandstone facies of the upper formations of the Osage group in the Louisville, Ky., region into the cherty limestone (Fort Payne) facies on going westward has been briefly described on a previous page of this report.

The Fort Payne very probably extends continuously beneath the basin of the western Kentucky coal field and is brought to the surface in outcrop on a pronounced anticlinal dome near Hicks, Hardin County, Ill. In this locality almost the entire thickness is exposed in the bed of Hicks Branch and is at the surface solid chert from top to bottom and 600 feet thick. Much of the chert is narrowly striped, gray and yellow. Some of it is brittle and minutely jointed so that it shatters easily; some is tough. The surface debris is commonly bounded by smooth even faces intersecting at all angles. Although Fort Payne is manifested on the outcrop only by chert, it is probably predominantly limestone at some distance below the surface where it has not been weathered, the cherty condition being a superficial phenomenon due to weathering, in which process the calcium carbonate of

*Bain, H. F., Fluorspar deposits of southern Illinois: U. S. Geol. Survey Bull. 255, 1905.

†Ulrich, E. O., The lead, zinc and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36, 1905.

‡Safford and Killebrew, Elements of the geology of Tennessee, 1900.

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the limestone has been replaced by silica. At one place a few feet of limestone was exposed and here the passage of the limestone at creek level into chert higher up on the bank could be plainly seen. The limestone exposed is medium thick-bedded, fine textured, and nearly black. No shale and no indications of shale within the formation were observed.

The determination of the thickness of the Fort Payne is based on an outcrop width on Hicks Branch of 2300 feet and an average dip of 15°, this average being the result of 18 dip measurements evenly distributed along Hicks Branch, which crosses the outcrop about normal to the strike. The above description of the Fort Payne both as regards character and thickness, differs greatly from the description of previous writers.

The Fort Payne is very sparsely fossiliferous. Although careful watch was kept and search made at various places, only a very few fossils were discovered which are listed below. As seen from the list these are too fragmentary for certain specific or in most cases even for certain generic determinations.

LIST OF FOSSILS FROM THE FORT PAYNE CHERT IN THE VICINITY OF HICKS, HARDIN COUNTY, ILL.

Productus burlingtonensis? Hall.
Productus setiger?
Rhynchopora? sp.
Solenomya? sp.
Sphenotus? sp.
Posidonomya? sp.
Aviculipecten sp.
Phanerotrema? sp.
Griffithides sp.

There is nothing specially significant for stratigraphy in this list. The forms all occur in the Osage group, although most of them have a larger range. The two species of Productus are apparently supposed to be confined to the Osage.

The lithologic similarity of the Fort Payne to the Burlington and Keokuk limestones is obvious. Its thickness is, however, more than twice that of the Burlington and Keokuk combined. The poor exposure of the forma-

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tion and the paucity of its organic remains make it impossible to discriminate its Burlington and Keokuk components, if indeed both are represented in it. It is generally accepted that the Fort Payne of other regions is strictly equivalent to the Keokuk limestone or its major part is so equivalent. There is no decisive fossil evidence that it contains any beds of Burlington age. It may be all Keokuk in Hardin County, Ill., and yet, on the other hand, its character, thickness, stratigraphic and geographic relations in that region afford reasons for regarding the presence of non-fossiliferous beds of Burlington age in its lower part as probable.

MERAMEC GROUP.

The Meramec group was established by Ulrich* to include in ascending order the Warsaw limestone, the Spergen ("Salem," "Bedford") limestone, and the St. Louis limestone. The group was named from Meramec River west of St. Louis, along which the formations composing the group outcrop.

WARSAW LIMESTONE.

The Warsaw limestone was so named by Hall† from Warsaw, Ill., on the Mississippi River. Along its eastern outcrop in Kentucky and Indiana, the Warsaw has been called the Harrodsburg limestone but as the equivalence of the beds so called with the typical Warsaw has been established the earlier name Warsaw is substituted for Harrodsburg. In the Louisville, Ky., and the adjoining southern Indiana regions, the Warsaw is composed of a variable succession of shale, limestone, and chert as shown in Plate 6.

In a few places the basal bed of the Warsaw, resting directly upon the Holtsclaw sandstone of the Osage group, is an oolitic limestone up to 2 feet thick. In other places at this horizon there is no oolitic limestone but instead a thin bed of dark green glauconitic clay.

Two types of limestone occur—a fine grained, siliceous, non-fossiliferous limestone and a highly crinoidal limestone. The former takes on a yellow hue on weather-

*Ulrich, E. O., U. S. Geol. Survey Prof. Paper 36.
†Hall, James, Am. Assoc. Adv. Sci., Vol. 10.

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ing and spalls off transversely to the bedding into irregular yellow chips by which the formation can be surely recognized. Limestone layers of this character usually have a good many geodes scattered through them and the ravines crossing their outcrop have, in their bottom, many geodes which have been derived from the geodiferous limestone layers. The geodes are hollow spheroidal or irregular bodies composed of silica and of all sizes, though generally not exceeding 4 inches in diameter. The walls of the cavity are usually richly studded with quartz crystals.

The crinoidal limestone is compact, thick bedded, and largely composed of crinoidal stem plates, many of which are of large size. Layers of yellow chert up to 1 foot thick are common, especially in the upper half of the formation. These cherts are full of sponge spicules.

PLATE 7A.

Photograph showing upper part of Warsaw limestone, which (the upper part) is a shale here, and lower part of St. Louis limestone. The basal bed of the St. Louis is cross bedded and crinoidal; the top bed of the Warsaw is an argillaceous limestone usually geodiferous. Spergen limestone absent. Old quarry about one-fourth mile west of Rock Haven, Meade County, Ky. Looking southwest.

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Shale generally forms but a small part of the formation, but in some sections as that at Edwardsville, Ind. (Plate 6), and at Rock Haven, Ky. (Section No. 34, Plate 3), it makes up a large part of the thickness of the Warsaw. It is largely a soft clay shale of bluish color. In the Edwardsville section the shale weathers gray and contains geodes and a few thin sandstone layers.

A photograph of this section is shown in Plate 7-A.

In western Kentucky the Warsaw outcrops in places in Caldwell and Lyon counties and probably in Trigg County. It is brought to outcrop just north of the Princeton fault where the latter crosses the railroad 2 miles north of Princeton and is there included in the area mapped as St. Louis limestone* and it is probable that more or less of the area mapped as St. Louis in the report cited is Warsaw. In the area mentioned, 2 miles north of Princeton, the Warsaw is recognized by its fossils and by the character of the chert in which they occur, the chert being just like that of the Warsaw around the Hicks dome in Hardin County, Ill.

In Hardin County, Ill., the Warsaw outcrops around the Hicks dome and from partial exposures in many places a fairly complete knowledge of it can be obtained. In this region it is proposed to include in the Warsaw the limestone lying between the Fort Payne chert below and the lowest beds containing the fossil coral *Lithostrotion proliferum* above, that fossil being taken as a marker for the base of the St. Louis limestone. The Spergen limestone is not known to be present in this section. The thickness of limestone thus included in the Warsaw is about 250 feet as determined by dip and width of outcrop on Hicks Branch.

The Warsaw in Hardin County is so far as exposed all limestone. Much the greater part of its thickness appears to be a very dark, fine-grained rock in layers up to 2 feet thick, some of which are rather thinly laminated, as revealed by weathering. Interbedded with these dark, fine-grained layers in the upper part at least of the Warsaw, are thick layers of very coarse-grained, light gray limestone. These coarse layers are largely composed of crinoid stem plates while the dark, fine-grained layers

*The lead, zinc, and fluorspar deposits of Western Kentucky: U. S. Geol. Survey Prof. Paper 36, Plate VIII.

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are usually crowded with fennestellid Bryozoa. These fine-grained layers also are more or less cherty, the chert occurring as irregular, scraggy plates or to some extent as even layers. In some exposures entire layers have been converted into chert. The coarse-grained layers also are largly changed on weathering to a peculiar reddish rusty, spongy, chert by which the Warsaw beds can be quite certainly identified. Chert of this character occurs in the Warsaw 2 miles north of Princeton, Ky.

The Warsaw is a highly fossiliferous formation, Bryozoa constituting a very large element of the fauna. The forms collected are listed below, all from Jefferson County, Ky., and adjacent parts of Indiana.

LIST OF FOSSILS FROM THE WARSAW LIMESTONE.

Sponge spicules.
Corals.
- Cladochonus beecheri? Grabau.
- Palaeacis carinata. Girty.
- Triplophyllum sp.
- Zaphrentis carinata. Worthen.

Crinoids.
- Echinocrinus sp.
- Synbathocrinus aff. swallowi. Hall.

Bryozoa.
- Archimedes negligens. Ulrich.
- Batostomella several species.
- Cystodictya sp.
- Cystodictya lineata. Ulrich.
- Fenestella several species.
- Fistulipora elegans?
- Fistulipora sp.
- Glyptopora sagenella, Prout.
- Hemitrypa sp.
- Lioclema gracillinum. Ulrich.
- Lioclema punctatum. Hall.
- Meekopora sp.
- Phractopora trifolia. Rominger.
- Pinnatopora aff. vinei. Ulrich.
- Polypora biseriata. Ulrich.
- Polypora sp.
- Rhombopora sp.
- Stenopora americana? Ulrich.
- Stenopora? sp.
- Streblotrypa major. Ulrich.

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Streblotrypa sp.
Worthenopora spinosa. Ulrich.

Brachiopods.

Athyris densa. Hall.
Avonia? n. sp.
Brachythyris gurleyi? Weller.
Brachythyris subcardiformis. (Hall.)
Camarotoechia? sp.
Dielasma sp.
Eumetria verneuilliana. (Hall.)
Orthotetes kaskaskiensis. (McChesney.)
Orthotetes keokuk? (Hall.)
Productus keokuk? Hall.
Productus magnus. Meek and Worthen.
Productus ovatus. Hall.
Productus setiger? Hall.
Productus semireticulatus. Martin.
Productus n. sp.
Pseudosyrinx keokuk? Weller.
Pustula alternata. (Norwood and Pratten.)
Pustula biseriata? (Hall.)
Pustula aff. indianensis. (Hall.)
Pustula punctata. (Martin.)
Reticularia setigera. (Hall.)
Reticularia sp.
Rhipidomella dubia. (Hall.)
Rhynchopora beecheri? Greger.
Spirifer bifurcatus. Hall.
Spirifer lateralis. Hall.
Spirifer tenuicostatus. Hall.
Spirifer washingtonensis. Weller.
Spiriferella neglecta. (Hall.)
Spiriferina aff. spinosa. Norwood and Pratten.
Spiriferina sp.
Syringothyris solidirostris. Weller.

Pelecypods.

Aviculipecten amplus. Meek and Worthen.
Aviculipecten sp.
Leptodesma n. sp.
Myalina sanctiludovici. Worthen.
Schizodus sp.

Gastropods.

Bellerophon sp.
Bembexia n. sp.
Euconispira sp.
Euomphalus quadrivolvis. Hall.
Euomphalus sp.
Fleurotomaria sp.

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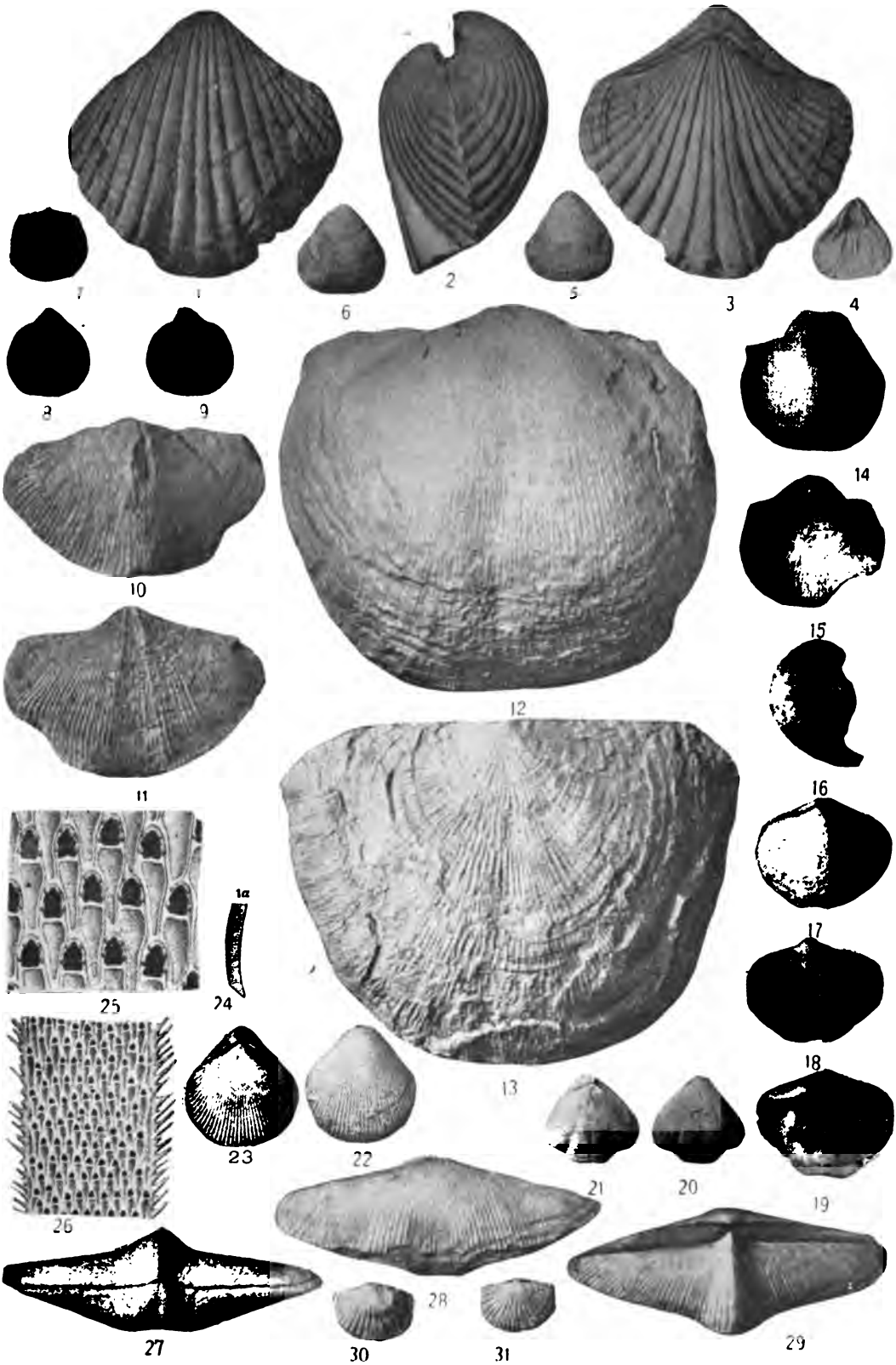

PLATE 8.

Fossils of the Warsaw, Spergen, and St. Louis limestones. All after Weller except Nos. 21-26.

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Several of the Warsaw fossils are illustrated on Plate No. 8.

FOSSILS OF THE WARSAW AND SPERGEN LIMESTONES. ALL AFTER WELLER EXCEPT NOS. 24-26.

Plate 8.

1-3 Brachythyris subcardiformis. (Hall.) 1, pedicle; 2, profile; and 3, brachial view. Warsaw and Spergen.

4-6 Rhipidomella dubia. (Hall.) 4, interior of pedicle valve; 5, brachial; 6, pedicle valve. Warsaw and Spergen. Common.

7-9 Echinoconchus (Plustula) biseriatus. (Hall.) 7, interior of a brachial valve; 8, pedicle; 9, brachial valve.

10-11 Spirifer tenuicostatus. Hall. 10, pedicle; 11, brachial valve. Rosewood shale to Warsaw limestone.

12-13 Productus magnus. Meek and Worthen. 12, pedicle; 13, brachial valve. Warsaw limestone only. Characteristic form.

14-16 Productus altonensis. Norwood and Pratten. 14, pedicle; 15, brachial; and 16, profile view. Spergen limestone. Productus aff. gallatinensis.

17-19 Athyris densa. Hall. 17, brachial; 18, pedicle valve; 19, interior of pedicle valve. Warsaw limestone.

20-21 Composite trinuclea. (Hall.) Pedicle and brachial valves. Spergen limestone.

22-23 Eumetria vernuiliana. (Hall.) Pedicle and brachial valves. Holtsclaw sandstone to Spergen limestone.

24-26 Worthenopora spinosa. Ulrich. Common and characteristic bryozoan of the Warsaw and Spergen limestones, 24, specimen natural size; 25 and 26, enlarged views. 26 shows the characteristic spines.

27-29 Spirifer lateralis. Hall. 27, cardinal; 28, pedicle; 29, brachial view. Warsaw and Spergen limestones.

30-31 Streptorynchus (Orthotetes) minutum. (Cummings.) Brachial and pedicle valves. Spergen limestone.

SPERGEN ("SALEM") LIMESTONE.

There has been considerable controversy over the name of the limestone here under description. In Indiana it has been called Bedford rock, Bedford oolitic limestone, and later (1901) Salem limestone. The name Spergen limestone, definitely adopted by the United States Geological Survey in 1904, after prior usage by various early writers,* and after consideration of the

*Lyon, S. S. (St. Louis Acad. Sci., Trans., vol. 1, p. 619, 1860); C. E. Siebenthal (Indiana Dept. Geol. and Nat. Res., 21st Ann. Rep., p. 298, 1897); S. Weller (Jour. Geol., vol. 6, p. 313, 1898); and H. S. Williams (Arkansas Geol. Survey, vol. 5, p. 348, 1900).

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widely established use of the terms Spergen Hill fauna and Spergen fauna, is used in this report. The original form, Spergen Hill beds, taken from Spergen Hill, Washington County, Ind., about 20 miles nearly north of Louisville, Ky., is, however, modified to Spergen limestone.

In Kentucky the Spergen is a thick-bedded, light gray, coarse-grained fossiliferous limestone 20 feet thick. It is not oolitic in Kentucky nor has it the qualities of the Bedford building stone. It caps a few of the high knobs in the southern part of Jefferson County, is well exhibited in the quarry at West Point and in the bluff and railroad cut at Pilchers Station on the Louisville, Henderson & St. Louis Railroad, 5 miles west of West Point. The Spergen is not present in the bluff at Rock Haven about 2 miles southwest of Pilchers and must die out between Pilchers and Rock Haven. See sections No. 34 and 35 of Plate 3. According to Ashley,* it thins out likewise in Indiana in the river bluff north of Rock Haven. It is likewise absent in the vicinity of Colesburg where the St. Louis limestone overlies the Warsaw limestone with an angular unconformity between them. (See Photographs, Plate 7-A, and Plate 9.) This thinning of the Spergen seems to proceed constantly and gradually southward from the region of Bedford, Ind., where the Spergen ("Bedford") has its maximum thickness of 150 feet. The Spergen is not certainly known west and south of the limits outlined above although there is a possibility that it is represented in Hardin County, Ill., by the upper part of the 250 feet of limestone classed as Warsaw in this report. The coarse-grained, crinoidal, light gray limestone layers in the upper part of that limestone bear a close resemblance to the Spergen limestone in Jefferson County, Ky., and southern Indiana. This is the more probable since the Spergen is recognized in the Mississippi Valley in western Illinois and eastern Missouri.

The Spergen limestone is highly fossiliferous. The forms collected in Jefferson County, Ky., are listed below.

*Ashley, G. H., Geology of the lower Carboniferous area of southern Indiana: Ind. Dept. Geol. and Nat. Res., Twenty-seventh Ann. Rept., pp. 49-122, 1903.

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LIST OF FOSSILS FROM THE SPERGEN LIMESTONE IN JEFFERSON COUNTY, KY., AND ADJACENT PARTS OF INDIANA.

Foraminifera.
- Endothyra baileyi. Hall.

Corals.
- Cladochonus beecheri. Grabau.
- Cladochonus sp.
- Triplophyllum sp.

Crinoids.
- Echinocrinus sp.
- Pentremites conoideus. Hall.
- Pentremites? sp.

Vermes (Worms.)
- Spirorbis annulata. Hall.
- Spirorbis sp.

Bryozoa.
- Batostomella sp.
- Cystodictya lineata. Ulrich.
- Cystodictya pustulosa. Ulrich.
- Dichotrypa? sp.
- Fenestella several species.
- Fenestella tenax? Ulrich.
- Fistulipora sp.
- Hemitrypa hemitrypa. Prout.
- Hemitrypa var. nodulosa. Ulrich.
- Hemitrypa sp.
- Lioclema sp.
- Meekopora? sp.
- Polypora biseriata? Ulrich.
- Polypora simulatrix? Ulrich.
- Polypora sp.
- Ptilopora valida. Ulrich.
- Rhombopora? sp.
- Stenopora sp.
- Worthenopora spatulata. Ulrich.
- Worthenopora spinosa. Ulrich.

Brachiopods.
- Brachythyris subcardiiformis. (Hall.)
- Camarotoechia? sp.
- Cliothyridina hirsuta. (Hall.)
- Cliothyridina parvirostus. (Meek and Worthen.)
- Cranaena sulcata? Weller.
- Crania sp.
- Composita trinuclea. Hall.
- Dielasma sp.
- Eumetria verneuiliana. (Hall.)
- Orthotetes aff. kaskaskiensis. (McChesney.)

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Productus aff. gallatinensis. Girty.
Productus keokuk. Hall.
Productus ovatus. Hall.
Productus setiger. Hall.
Productus n. sp.
Pustula alternata. (Norwood and Pratten.)
Reticularia setigera. (Hall.)
Rhynchopora sp.
Schuchertella minuta? (Cumings.)
Spirifer bifurcatus. Hall.
Spirifer lateralis. Hall.
Spirifer tenuicostatus. Hall.
Spirifer washingtonensis. Weller.
Spiriferella neglecta. (Hall.)
Tetracamera arctirostrata? Swallow.

Pelecypods.

Allerisma maxvillense? Whitfield.
Conocardium aff. catastomum. Hall.
Conocardium sp.
Cypricardella subelliptica? (Hall.)
Cypricardinia indianensis? Hall.
Cypricardinia sp.
Deltopecten sp.
Leptodesma spergensis. Whitfield.
Leptodesma sp.
Myalina sp.
Pteronites? sp.
Worthenia? sp.

UNCONFORMITY.—In areas in which the Spergen limestone is absent, the St. Louis limestone lies upon the Warsaw limestone. The absence of a formation, as in this case, constitutes a stratigraphic gap or hiatus, technically known as an unconformity. This unconformity is further attested by certain necessarily associated phenomena. In every section between Rock Haven and Brandenburg, in Meade County, in which the contact of the Warsaw and St. Louis is shown, the basal St. Louis layers are cross bedded and fragmental or have lenses of such rock. The fragmental limestone is composed of broken shells, crinoidal joints, etc. The material is of such a character as might have been heaped up on a beach by the action of waves. The thick-bedded basal St. Louis layers above the contact shown in the photograph, Plate 9, are of this character. Another evidence of unconform-

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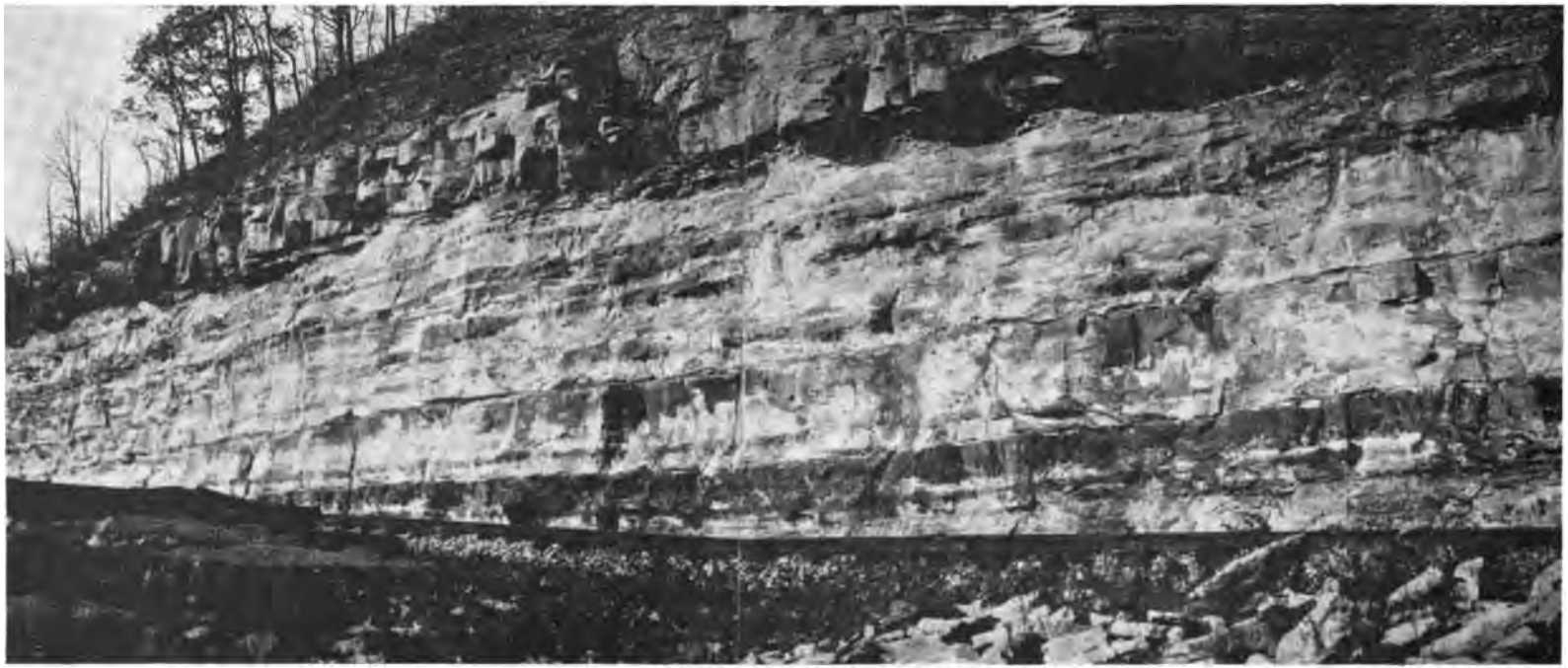

PLATE 9.

Photograph of unconformable contact between the Warsaw and St. Louis limestones. Spergen limestone absent. Cut on the Louisville & Nashville railroad, about 1 mile south of Colesburg, Hardin County, Ky.

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ity is exhibited in a cut on the Louisville & Nashville Railroad about 1 mile south of Colesburg. Here the St. Louis limestone lies upon beveled edges of layers of typical Warsaw limestone as shown in the photograph, Plate 9.

In this photograph is clearly shown that the higher Warsaw layers on the left have been successively removed on going to the right so that at the right hand end of the cut the practically horizontal basal St. Louis layers rest upon the beveled edges of Warsaw layers 20 to 25 feet lower than those upon which it rests at the left hand end. The distance shown is about 150 feet.

The explanation of these facts just expressed is as follows: Generally absence of a stratigraphic unit from any area results from such area having been dry land either, first, during the time of deposition of the stratum elsewhere, or second, subsequently to its deposition. In the first case the stratum was never deposited where it is now absent; in the second case, the stratum was eroded away during the dry land period subsequent to its deposition.

Necessarily connected with land is coarse, cross-bedded material such as accumulates along a sea beach, a bed of conglomerate full of pebbles rounded by wave action or a layer composed largely of broken shells, fragments of dismembered crinoid skeletons, etc. Likewise discordance of bedding results from a stratum having been elevated above sea level, tilted in the process, and then eroded to a flat surface, upon which the basal layers of the next overlying formation are laid down.

Upon such evidence as that presented above, the existence of a geographically extensive unconformity at the base of the St. Louis limestone in western Kentucky is affirmed.

ST. LOUIS LIMESTONE.

The name St. Louis has been in use for many years, the limestone formation to which it is applied being prominently developed and displayed along the Mississippi River bluffs in the vicinity of St. Louis, Mo. This limestone formation is widely distributed throughout southern Illinois, Indiana, western Kentucky, and

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Tennessee, and the name, St. Louis, has been universally applied to it in those regions.

In Kentucky the St. Louis outcrops in a wide, semicircular belt from Meade County to the Kentucky-Tennessee line, thence westward and northwestward through Trigg, Lyon and Livingston counties, Ky., to Ohio River and into southeastern Illinois. According to locality the inner edge of this belt is 10 to 20 miles distant from the margin of the coal field. From its outcrop the limestone dips at all points toward the coal field which it underlies at considerable depths.

The St. Louis wherever examined by the writer is all limestone. The layers are predominantly rather thick, but thin-bedded segments occur in some sections, and some of the thicker layers reveal a laminated or shaly structure on weathering. (See photo, Plate 7-B.)

PLATE 7B.
St. Louis limestone in quarry at Jacks Point, one-half mile southwest of Elizabethtown, Hardin County, Ill. Looking northwest.

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In texture it ranges from coarsely crystalline to compact. The great bulk of the formation probably should be classed as medium to fine grained. One or more layers of lithographic texture occur locally in the beds 80 to 150 feet above the bottom. The very coarse-grained layers, of which apparently there are but few, have been noted mainly near the bottom.

The color of the fresh limestone ranges from dark gray or nearly black to light gray, probably the greater part of the formation being of medium dark gray color. None of the specimens collected by the writer are indicated by acid test to be highly magnesian. These specimens cover seemingly about the whole range of variation in appearance of the formation from top to bottom. Much of the formation evidently contains considerable silica as shown by the abundance of chert which develops on weathering apparently by segregation of the included disseminated silica, and makes a striking feature of many weathered outcrops on which it appears as projecting surficially black layers or lines of black nodules. The St. Louis chert is quite largely in the form of irregular surfaced flattish pieces. The formation contains layers of lithographic stone which are highly argillaceous and some of which on extreme weathering, break down into clay. These are best developed in the vicinity of Brandenburg, Ky. In the eastern areas of its outcrop as in Hardin County, Ky., along the Louisville & Nashville Railroad on the escarpment from Colesburg to Tunnel Hill about 3 miles north of Elizabethtown, the St. Louis contains several layers of earthy and siliceous limestone with geodes. Beds of this character bear a close resemblance to the geodiferous beds in the Warsaw which immediately underlies the St. Louis in this section. They are distributed through the full thickness of the St. Louis in that section, as shown by section No. 31, Plate 3. Such beds occur also in the lower part of the St. Louis at Rock Haven but were not observed farther west. They seem to be an eastern development. There is an important negative feature of the St. Louis —it is practically non-oolitic. At least, with a single somewhat doubtful exception, no oolitic limestone has been observed by the writer, and his observations are

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corroborated by those of others. In this respect the St. Louis differs from the Ste. Genevieve.

The thickness of the St. Louis seems to vary from 300 to 500 feet. In southern Illinois conditions are such that accurate measurements are impossible, but from dip and width of outcrop the thickness seems to be not less than 300 feet. East of the western coal field in Kentucky the thickness is 500 feet as measured along the Louisville & Nashville Railroad between Colesburg and Tunnel Hill. It extends to the highest ground above the tunnel at Tunnel Hill, as evidenced by the occurrence of *Lithostrotion basaltiforme (canadense)* in the residual chert.

Economically the St. Louis is suitable for road metal and probably there are beds that could profitably be utilized for agricultural lime, either burned or ground. Its impurities such as silica, alumina, and possibly magnesia disqualify it for use in cement making. For this use uniformity of composition is demanded in order to calculate with certainty the proportion of the raw materials entering into the cement mixture, and such uniformity is more likely to prevail in a high calcium carbonate limestone than in one containing a large percentage of impurities.

The lithographic stone in the vicinity of Brandenburg has been exploited to some extent. (See sections Nos. 33 and 33a, Plate 3.) The stone, which does not seem to meet with the favor of lithographers for the highest grade of work, is yet in good demand and the Brandenburg quarry had a large output in 1916.

Many layers of the St. Louis limestone are abundantly fossiliferous, but the fossils are usually very tightly enclosed in the rock and are revealed only by weathering. On weathered edges many layers can be seen to be a thick mat of fennestellid Bryozoa. The fossils are especially well revealed as external casts or internal moulds in much of the abundant chert debris that strews the areas of outcrop of the limestone. Such identifiable species as have been collected in the course of field work for this report are listed below.

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LIST OF FOSSILS FROM THE ST. LOUIS LIMESTONE MAINLY FROM BRECKINRIDGE, MEADE, AND HARDIN COUNTIES, KY.

Syringopora sp.
Cladochonus sp.
Lithostrotion proliferum. Hall.
Lithostrotion basaltiforme. Owen.--L. canadense (Castelnau.)
Zaphrentis carinata. Worthen.
Meniscophyllum sp.
Hapsiphyllum calcariforme. (Hall?)—Zaphrentis calciformis. Hall?
Melonitis Multiporus.
Platycrinus huntsvillae. Wachsmuth and Springer.
Pentremites cavus. Ulrich.
Pentremites conoideus. Hall.
Stenopora sp.
Batostomella sp.
Fistulipora sp.
Fenestella sev. sp.
Polypora sev. sp.
Cystodictya lineata. Ulrich.
Cystodictya pustulosa Ulrich.
Dichotrypa sp.
Worthenopora spinosa. Ulrich.
Rhipidomella dubia. Hall.
Schuchertella? sp.
Orthotetes kaskaskiensis (McChesney.)
Productus scitulus. Meek and Worthen.
Productus altonensis? Norwood and Pratten
Productus aff. viminalis. White.
Productus ovatus. Hall.
Pustula indianensis? (Hall)
Pustula biseriata. (Hall.)
Camarotoechia mutata. Hall.
Girtyella indianensis? (Girty)
Tetracamera arctirostrata. (Swallow.)
Spiriferella n. sp.
Spiriferina salemensis. Weller.
Spirifer pellaensis. Weller.
Spirifer bifurcatus. Hall.
Spirifer tenuicostatus. Hall.
Brachythyris subcardiiformis. (Hall.)
Reticularia setigera. (Hall.)
Reticularia n. sp.
Composita trinuclea. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria verneuiliana. (Hall.)
Allerisma sp.

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Streblopteria aff. herzeri.
Aviculipecten sp.
Schizodus sp
Bellerophon sublevis? Hall.
Bucanopsis textilis? (Hall.)
Euomphalus sp.
Platyceras sp.
Nautilus sp.
Griffithides sp.

A few of these fossils are illustrated on Plates 5, 8, 10 and 11.

Lithostrotion basaltiforme commonly known as *L. canadense* is confined to the St. Louis and being fairly abundant and generally distributed serves for the identification of the St. Louis. *L. proliferum* begins with the St. Louis but extends upward into the bottom of the Ste. Genevieve limestone. This form is usually found as separated silicified coralites as shown by figures 15 and 16, Plate 10, though growing in large clusters like those shown in figure 17, Plate 10. They can be distinguished from similar forms of other genera by the conical prominence in the cup at the larger end so well shown in figure 17. *L. basaltiforme (canadense)* (Plate 11) commonly exists as chert chunks of considerable size in which the outlines of the coralites and their internal septa and tabulae are greatly obscured but which, by close observation, can be detected in many pieces of chert that to ordinary observation look like an ordinary piece of rock.

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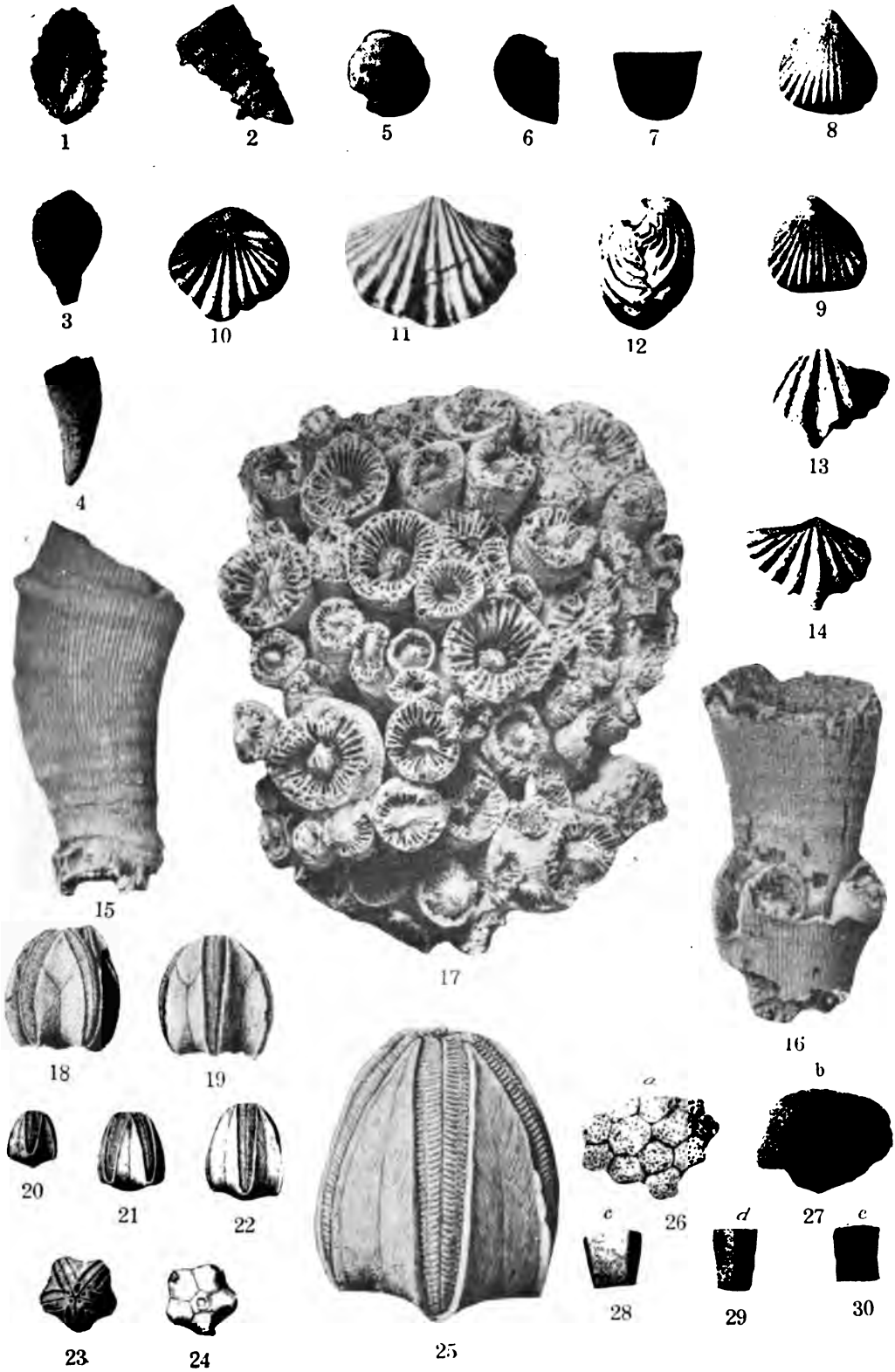

PLATE 10.

Warsaw, Spergen, St. Louis, and Ste. Genevieve fossils.

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1

2

PLATE 11.

Fossils of the St. Louis limestone.

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WARSAW, SPERGEN, ST. LOUIS AND STE. GENEVIEVE FOSSILS.
Plate 10.

1-2 Stem plates of a species of Platycrinus. Natural size. No. 1, a separated plate showing a border of strong spines. No. 2, piece of a twisted stem composed of several plates like that shown in figure 1. Common in the Warsaw of Hardin County, Illinois, and a few specimens found in the Warsaw of Jefferson County, Ky. Seems characteristic of the Warsaw; similar to Platycrinus huntsvillae of the Ste. Genevieve limestone, but much larger. Compare figures 1-2, Plate 14. Specimens from Hardin County, Ill.

3-4 Triplophyllum sp. A common small cup coral of the Warsaw. No. 3, a small specimen X 2 preserving the cup and showing the principal and two lateral fossae. No. 4, side view of another specimen, natural size. Specimens from Hardin County, Ill.

5-7 Productus scitulus. Meek and Worthen. Apparently confined to the St. Louis limestone. After Weller. Specimens from St. Louis limestone, St. Louis, Mo.

8-9 Tetracamera arctirostrata. (Swallow.) After Weller. Specimens from Spergen limestone, Booneville, Mo. Occurs in St. Louis limestone, near top, at Tunnel Hill, Hardin County, Ky.

10-12 Spirifer bifurcatus, Hall. No. 10, from Spergen limestone, Spergen Hill, Ind. Nos. 11-12, from Spergen limestone, Alton, Ill. After Weller. Warsaw to St. Louis limestone. Doubtfully also in Ste. Genevieve limestone. See list.

13-14 Spiriferina salemensis. Weller. Specimens from Spergen limestone, Bloomington, Ind. Spergen and St. Louis limestones. After Weller.

15-17 Lithostrotion proliferum. Hall. After Ulrich.
Nos. 15-16, side views of individual coralites detached from the colony. No. 16 shows the bases of the proliferous buds of new coralites by which the specific name was suggested. No. 17, a colony seen from above showing the manner of growth and cups with the radiating septa and the conical prominences in the bottom. St. Louis and lower part of the Ste. Genevieve limestones.

18-19 Pentremites cavus. Ulrich. After Ulrich. Specimens from 4 miles northwest of Princeton, Caldwell County Ky.

20-25 Pentremites conoidens. Hall. After Ulrich. No. 25, same as No. 22, magnified three times. Four miles northwest of Princeton, Caldwell County, Ky.

26-30 Melonites multiporus. Owen and Norwood. After Ulrich. Plates of an echinoid or ancient sea urchin full of small pores. Generally common to abundant in the lower part of the St. Louis limestone.

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ST. LOUIS FOSSILS.

Plate 11.

1-2 Lithostrotion basaltiforme. Owen. After Ulrich. Same as L. canadense (Castelman), by which name it has long been known. So far as known confined to the St. Louis limestone.

STE. GENEVIEVE LIMESTONE.

(Grouping in dispute.)

The name Ste. Genevieve is from Ste. Genevieve, Mo. The limestone to which the name applies has commonly not been differentiated from the St. Louis limestone, the St. Louis proper and the Ste. Genevieve having usually been combined under the name St. Louis, but Shumard* as early as 1857 and Ulrich† in 1905 recognized the differences between the two limestones and treated them as separate formations.

The Ste. Genevieve limestone outcrops in a broad belt lying between the outcrop of the St. Louis and the coal field. Irvington, Stephensport, Munfordville, Bowling Green, Russellville, Elkton, Hopkinsville, and Princeton are located on the Ste. Genevieve limestone and roughly mark its outcrop, which is also indicated by the numerous exposures of thick-bedded, white weathering limestone along the railroads and in the adjacent fields. None of the other limestone formations of the region exhibit this feature, at least not to such a notable degree.

The Ste. Genevieve limestone is locally at least separated from the St. Louis limestone by an unconformity. The best evidence of this is found on St. Laurens Creek a few miles southwest of St. Marys, Mo. Here, as pointed out by Weller, residual silicified corals and brachiopods of Devonian age occur in a foot or two of limestone above which the limestone is of Ste. Genevieve character (oolitic) and bears characteristic Ste. Genevieve fossils and below which oolite seems to be absent and the limestone appears to be more likely of St. Louis age. Other places where good evidence of this unconformity are displayed are Monte Sana near Huntsville, Ala., and near Chattanooga, Tenn. However, in Ohio Valley and throughout Kentucky there is no physical evidence of

*Shumard, B. F., St. Louis Acad. Sci., Trans. Vol. 1, p. 406, 1857.
†Ulrich, E. O., Lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36, pp. 39-52.

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a break between the two formations discernible. This is true even where the contact has been observed which is in but few places. It by no means follows, however, that no break exists because it cannot be detected.

In the few places where the contact is supposed to have been seen there is no easily recognizable difference between the St. Louis and Ste. Genevieve. The two limestones are differentiated by characters distinct and discernible enough on close examination but not obvious to careless inspection. The distinguishing characters are both lithologic and paleontologic. The distinguishing lithologic character of the Ste. Genevieve is its oolite described a little further on. No oolite has been observed in the St. Louis, although there may be some in it. Paleontologically the St. Louis is distinguished by the presence of *Lithostrotion basaltiforme*, Owen, (*Lithostrotion canadense*) which has not been found in the Ste. Genevieve while the Ste. Genevieve is marked by the Crinoid, *Platycrinus huntsvillae*, which has not certainly been found in the St. Louis. (See Plates 11 and 14 for pictures of these fossils.) So far as yet known these two fossils have not been found in the same beds, although the writer collected them at one point in Illinois in layers of limestone in contact with each other and otherwise indistinguishable, *Lithostrotion basaltiforme (Canandense)* being in the lower and *Platycrinus huntsvillae* in the upper layer. The writer's practice has been to place all oolitic beds in this part of the general section and all beds with *Platycrinus huntsvillae* in the Ste. Genevieve, and the practice has so far given consistent results.

According to the usage of the United States Geological Survey the Ste. Genevieve limestone is divided into three members. Beginning with the lowest these are the Fredonia oolite, Rosiclare sandstone, and Ohara limestone members.

FREDONIA OOLITE MEMBER.—The Fredonia oolite is interesting for its abundant sink holes and caves. Mammoth Cave is mainly, if not entirely, in the Fredonia. The name is from Fredonia, Caldwell County, Ky., which is located on a large area of this limestone.* The

*Ulrich, E. O., U. S. Geol. Survey Prof. Paper 36.

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Fredonia member is largely a coarsely oolitic and thick-bedded limestone † of predominantly light gray color, an occasional layer being very dark colored. Some of the oolitic layers are compact and brittle and have a glassy fracture and its oolitic character can be seen only on close inspection. As a general rule, however, the rock is coarse textured, has a strong fracture, and the minute spheroidal bodies are conspicuous, standing out prominently on weathered surfaces and being plainly apparent on freshly broken surfaces. The oolite layers commonly are composed also, in part, of fragmented fossils of which the stem plates of crinoids are most abundant. Such fragmental limestone usually has a coarsely crystalline aspect. The light gray to nearly white oolitic beds 10 to 30 feet thick are conspicuous features in any exposure of a considerable thickness of the Fredonia member, as in a quarry face. (See Plates 12 and 13.) The oolitic beds in some cases or perhaps generally, are more or less strongly cross-bedded, this structure becoming apparent usually only on surfaces etched by weathering.

This phenomena is illustrated in the photograph, Plate 12B. Usually the cross-bedding is not as strong as shown in this photograph but is only a delicate cross lamination in thick or massive layers unbroken by bedding planes.

Besides its oolitic constituent the Fredonia contains a considerable proportion, say one-third, of non-oolitic limestone varying from compact to crystalline and from rather dark or drab to light gray in color. The oolitic and non-oolitic layers are interbedded throughout the member. A lithologic feature hardly less notable and characteristic than the oolite is the compact brittle rock with glassy or conchoidal fracture, of pearl-gray, dove, or darker gray color, and weathering with a white chalky crust. Such limestones, both oolitic and non-oolitic, make a considerable proportion of the Fredonia. The Fredonia yields much chert on weathering and surfaces underlain by it usually have much chert in the residual soil resulting from the decomposition of the limestone. The chert is generally yellowish on the outside, being

†Oolite or oolitic limestone is so called from the fact that it contains or is largely composed of small spherical or spheroidal bodies like fish eggs. See Plate 18.

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PLATE 12A.

View of quarry at New Mystic, Breckinridge County, Ky., showing the upper part of the Fredonia oolite member of the Ste. Genevieve limestone. These beds immediately underlie those shown at the bottom of Plate 16. Layer with Lithostration harmodites shown in Plate 18A about at the level of the bottom of quarry.

PLATE 12B.

Photograph of a cross-bedded layer in the Fredonia oolite member. Cut on Fordsville Branch of Louisville, Henderson & St. Louis railroad, 2 miles south of Irvington, Breckinridge County, Ky. Looking west.

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stained by iron oxide. Inside, fresh chert is likely to be bluish gray, flinty, and of waxy lustre, but on weathering it is generally changed to a light or yellowish gray or nearly white color and to a chalky texture. The chert is formed from the limestone by silicification of the latter, and in case the original rock was oolitic the resulting chert preserves the oolites which are also silicified. Much of the Fredonia chert in the region east of the coal field is in tabular pieces with smooth parallel faces, a characteristic that is not common in the underlying St. Louis chert. In western Kentucky and southern Illinois this difference does not appear to hold. The tabular form is due to the fact that entire thin even layers of limestone have undergone silicification. The thickness of the Fredonia in Breckinridge County is 160 feet and on Ohio River at and above Rosiclare, Ill., it is 180 feet.

The Fredonia oolite is moderately fossiliferous in Breckinridge and Meade counties, but abundantly so ap-

PLATE 12C.

Photograph of a large mass of the coral Lithostrotion harmodites. Railroad cut just east of New Mystic, Breckinridge County, Ky. Layer about at the level of the bottom of the quarry shown in plate 12A.

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parently in Caldwell and Crittenden counties where Ulrich obtained the large collection listed in his paper, this volume.

One of the most interesting and notable forms in Breckinridge County is the coral *Lithostrotion harmodites*, which crowds some layers and forms large heads such as shown in the photograph, Plate 12-c. In most localities large forms seem not to be abundant, but the oolitic beds are especially noteworthy for the number and variety of diminutive forms, which to a large extent are the same as the diminutive species so characteristic of the fauna of the oolitic Spergen limestone at its type locality, Spergen Hill, Washington County, Ind., from which the Spergen limestone and fauna take their names. This fauna recurs in the Fredonia oolite as well as in oolite beds at higher horizons. It evidently flourished under the conditions under which the oolitic limestone was formed and reappeared whenever and wherever those conditions were re-established in later Mississippian time.

The oolitic beds are of high purity and are suitable for chemical lime and for lime and ground limestone for agricultural use. The limestone used for cement manufacture by the Kosmos Portland Cement Co., at Kosmosdale, Jefferson County, Ky., is Fredonia, being obtained from the bluff of Ohio River 7 miles below Brandenburg, Meade County, Ky. The quarries for lime, road metal, and ballast at Webster and Mystic in Breckinridge County are in the Fredonia mainly, and the large quarry at Cedar Bluff near Princeton in Caldwell County is in the Fredonia and Ohara members. A photograph of this quarry is shown in Plate 13.

The Fredonia everywhere is the main mass of the Ste. Genevieve limestone and is the member exposed at the type locality, Ste. Genevieve, Mo. It is remarkable for its geographic extent, which roughly is from Ste. Genevieve, Mo., east to the north end of Sequatchie Valley, Tenn., south to Huntsville, Ala., and north into southeastern Iowa; and it is not less remarkable for the persistence of its peculiar lithologic and paleontologic features.

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Bethel S. S.

Upper Ohara { 4, 3, 2

Conglomerate

Lower Ohara 1
Rosiclare S. S.

Fredonia oolite.

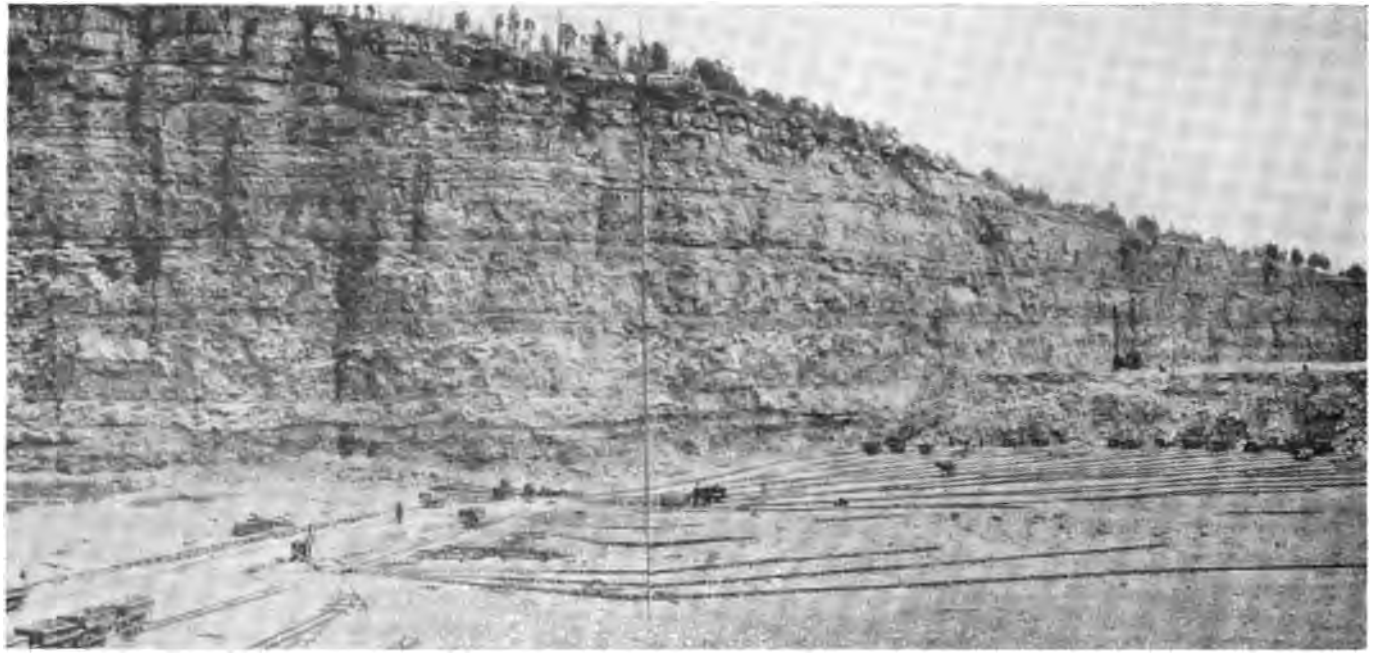

PLATE 13.
Photograph of quarry in Fredonia and Ohara members of the Ste. Genevieve limestone at Cedar Hill (Ohara), 3 miles southeast of Princeton, Caldwell County, Ky. Looking northeast Numbers to left of Ohara section refer to Ulrich's divisions.

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ROSICLARE SANDSTONE MEMBER.—The Rosiclare sandstone, named from Rosiclare, Hardin County, Ill., where it outcrops as a conspicuous ledge 60 feet above Ohio River, is a thin stratum between the Fredonia oolite member below and the Ohara limestone member above. It is thus intercalated in pure thick-bedded oolitic limestone, the immediately overlying layers of the Ohara being also oolitic. The sandstone varies from 1 to 2 feet to perhaps 10 or 15 feet in thickness. Ten feet is the greatest thickness actually observed.

A fresh specimen of Rosiclare sandstone from Cedar Bluff quarry southeast of Princeton, Ky., is sufficiently calcareous to effervesce freely in acid. The residue obtained by dissolving out the calcium carbonate from a piece of this specimen was composed of angular grains of quartz .02 to .2 of a millimeter in diameter. In some specimens of weathered sandstone in which the calcium carbonate has been leached out, rhombohedral cavities formerly occupied by calcite crystals are present. On weathering and leaching the sandstone becomes friable in texture and yellowish or reddish in color.

Considering its small thickness, the Rosiclare is remarkable for its geographical extent. It is known from Cerulean, Trigg County, Ky., northwestward through Caldwell and Crittenden counties, Ky., throughout Hardin and Pope counties, Ill., and is believed to be a persistent bed throughout, being present everywhere that observations are possible and have been made at its horizon. A bed of the same character and thickness is present in the same stratigraphic position in the Ste. Genevieve limestone along Mississippi River in Ste. Genevieve County, Mo., and in Monroe and Union counties, Ill., and is probably the Rosiclare. Its northwest-southeast extent is thus at least 200 miles.

No fossils have been observed in the Rosiclare although they are plentiful in the immediately overlying and underlying limestone layers.

The Rosiclare sandstone is also worthy of special note as marking the beginning of the sandstone deposition in the Mississippian series of the Mississippi and lower Ohio Valley region. Sandstone strata become a prominent feature of the Chester group above the Ste. Genevieve limestone as shown in the following pages of

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this report. Since sandstone is practically unknown in the Mississippian formations of the region between the Kinderhook group and the Rosiclare sandstone, the deposition of this sandstone marks an important change in the geographic conditions affecting the source and distribution of sediment.

OHARA LIMESTONE MEMBER.—The name Ohara, applied to this member by Ulrich,* was taken from the former name, Ohara, of the post office and quarries now known by the name Cedar Hill or Cedar Bluff, 3 miles southeast of Princeton, Ky. The Ohara member is composed of limestone and shale, the former largely predominating. For convenience of reference to Ulrich's discussion of the fossils of the Ohara, the following section of the Ohara at Cedar Hill is given, the divisions being numbered as by Ulrich:

SECTION OF THE OHARA LIMESTONE MEMBER OF THE STE. GENEVIEVE LIMESTONE AT CEDAR HILL, 3 MILES SOUTHEAST OF PRINCETON, KY.

			Feet.
	Sandstone, Bethel (Aux Vases of Ulrich)		10+
4.	Limestone, cherty, fossiliferous	upper Ohara.	18
3.	Shale with limestone, fossiliferous		20
2.	Limestone, shale partings, highly fossiliferous		33
	Conglomerate		1
1.	Limestone, oolitic beds	lower Ohara	25
		Total Ohara..	97
	Sandstone, Rosiclare member		2

The limestone includes thick-bedded, thin-bedded, compact, granular, and oolitic layers.

About 25 feet above the Rosiclare sandstone in the section at Cedar Bluff is a layer of limestone breccia or conglomerate, forming the bottom of No. 2 of preceding section. This is about 1 foot thick and overlying is a layer 1½ feet thick of oolitic limestone with abundant small quartz grains. The 25 feet of limestone between the Rosiclare sandstone and the conglomerate layer

*Ulrich, E. O., Loc. Cit.

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above mentioned (No. 1,) is thick-bedded, light gray, and includes compact, oolitic and fragmental granular layers. This segment is designated the lower Ohara. *Platycrinus huntsvillae,* the characteristic Fredonia fossil, is fairly abundant in this limestone up to the conglomerate but is rare above the conglomerate. In fact, this segment of the Ohara which persists from Cedar Bluff to Rosiclare, Ill., having been seen in every examined section in which the limestone is exposed, is lithologically much more like the Fredonia oolite than like the overlying remainder of the Ohara member.

Overlying the conglomerate forming the base of division No. 2 is 33 feet of limestone with shale partings. At the bottom just above the conglomerate layer is a layer of gray siliceous oolite 18 inches thick, containing a plentiful sprinkling of quartz and sand grains. This layer is similar to the one at the base of the Gasper oolite in Breckinridge County, which also has a conglomerate layer just beneath it. The overlying beds however in the two cases are quite different both lithologically and paleontologically. The rest of division No. 3 is made up of thick and thin layers of bluish and gray limestone, varying through granular, compact or glassy, and earthy texture. It contains no conspicuous oolite layers like those in the Fredonia and lower Ohara.

Most of the shale of the Ohara is in a persistent bed, No. 3 of the preceding section, 10 to 20 feet thick, whose top generally lies 10 to 40 feet below the bottom of the Bethel sandstone. This shale includes limestone layers. It is highly fossiliferous and the source of many of the Ohara species of fossils. Thin shale partings occur also in the limestone of the Ohara member. As a general rule the shale is of the soft, greenish or bluish character usual in the Mississippian rocks of the region, but in the section 1 mile north of Princeton are layers of red shale up to 3 feet thick in the main shaly bed below the Bethel sandstone and very thin red layers were noted elsewhere.

The top beds of the Ohara, No. 4, immediately underlying the Bethel sandstone, are thick, fine-grained, dark gray limestone, generally cherty. At Downeys Bluff, Rosiclare, Ill., there are a few feet of thin-bedded to shaly limestone at the top of this division. Here, too

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the thickness seems greatest, being about 40 feet. Its usual thickness is 15 to 20 feet. No oolite has been observed in it. This division is also persistent, having been identified by its chert and fossils from a point north of Cobb, Caldwell County, Ky., to Carrsville, Livingston County, on Ohio River and farther northwest in Hardin County, Ill. Locally, as 2 miles north of Cerulean, this cherty limestone is absent and the Bethel sandstone rests upon the shale of No. 2. Even where it is not exposed the presence of this cherty division close below the Bethel sandstone is revealed by abundant small, rectangular faced, surficially whitish chert fragments and in places also by a considerable number of silicified fossils, especially *Pentremites princetonensis* and several of its varieties and mutations, as listed in Ulrich's paper, this volume; and by brachiopods, of which *Cliothyodina sublamellosa* is most common and abundant.

The general character and vertical distribution of the various components of the Ohara are well represented by the sections at Cedar Bluff and Downeys Bluff, Nos. 2 and 3 of Plate 3. The general appearance as developed at Cedar Bluff is shown in Plate 13.

As already stated the Fredonia member is highly fossiliferous. The following list, which is made up mainly of specimens collected in Breckinridge County, shows the character of the fauna of the Fredonia member. The same general fauna has been collected also in Crittenden and Caldwell counties and is listed in Ulrich's paper, this volume. In that region occur certain corals such as *Cystelasma* and *Michilinia* that have not been found in Breckinridge County.

LIST OF FOSSILS FROM THE FREDONIA OOLITE MEMBER OF THE STE. GENEVIEVE LIMESTONE MAINLY FROM BRECKINRIDGE AND MEADE COUNTIES.

Chaetetes? sp.
Syringopora sp.
Lithostrotion harmodites. Edwards and Haime.
Triplophyllum spinulosum. Edwards and Haime.
Campophyllum n. sp.
Pentremites princetonensis. Ulrich
Mesoblastus glaber. Meek and Worthen.
Platycrinus huntsvillae. Wachsmuth and Springer.

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Batocrinus? sp.
Fenestella sev. sp.
Polypora sev. sp.
Cystodictya sp.
Rhipidomella dubia. (Hall.)
Orthotetes kaskaskiensis. (McChesney.)
Productus ovatus. Hall.
Productus parvus. Meek and Worthen.
Diaphragmus elegans. Girty.
Pustula (Echinoconchus) genevievensis. (Weller.)
Pugnoides ottumwa. (White.)
Girtyella indianensis. (Girty.)
Spirifer pellaensis. Weller.
Spirifer bifurcatus? Hall.
Composita trinuclea. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria verneuiliana. (Hall.)
Allerisma aff. Maxvillense. Whitfield.
Sphenotus monroensis.
Deltopecten monroensis? (Worthen.)
Conocardium aff. meekanum. Hall.
Schizodus depressus. Worthen.
Astartella n. sp.
Pleurotomaria sev. sp.
Solenospira? sp.
Bellerophon sublaevis. Hall.
Euomphalus similis.
Euomphalus similis var. planus.
Straparollus spergenensis. Hall.
Cyclonema subangulatum?
Naticopsis n. sp.
Platyceras sp.

A notable feature of the Fredonia fauna is the numerous representation of the small fossils first appearing at an earlier date in the Spergen limestone, notably at Spergen Hill, Ind. These forms are especially prominent in Ulrich's list from the Fredonia of western Kentucky. This is a good example of a recurrent fauna. It reappears a second time in the Gasper oolite and a third time in oolitic layers of the still younger Okaw formation of southwest Illinois. This recurrent group of fossils evidently found a congenial environment in the conditions under which oolitic limestones were formed for it always occurs in the oolitic layers of the

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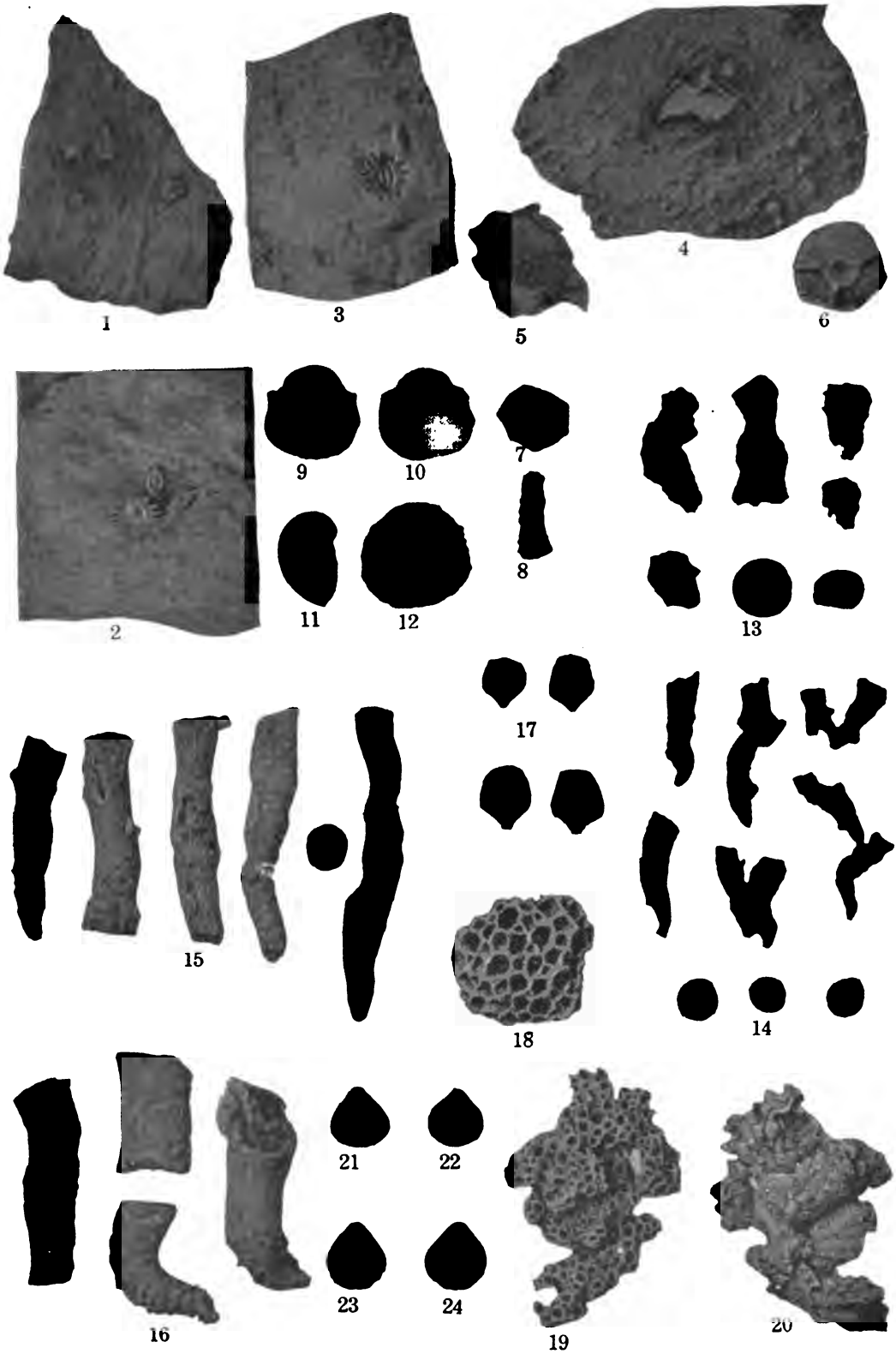

PLATE 14.

Fossils mainly from the Fredonia oolite member of the Ste. Genevieve limestone.

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formations in which they are found. This fauna is fully listed and discussed by Ulrich, this volume.

A number of characteristic Fredonia fossils are illustrated on Plate 14.

MAINLY FOSSILS OF THE FREDONIA OOLITE MEMBER OF THE STE. GENEVIEVE LIMESTONE.

Plate 14.

1-8 Platycrinus huntsvillae, Wachsmuth and Springer.

1-2 Stem plates attached to limestone. Elliptical plates with their fringe of radiating spines. Natural size. Common occurrence in the Fredonia oolite and highly characteristic of it. 3, mould of a stem plate in chert. Common in chert from the Fredonia oolite; 4-6, bases of P. huntsvillae showing the three radiating carinae characteristic of the species; 4, base attached to limestone, most common mode of occurrence; 5, base and radial plates showing ornamentation; 6-7, bases showing three carinae and ornamentation. After Ulrich. 8, piece of stem composed of several spiny plates and showing the twisted stems peculiar to the genus Platycrinus. After Ulrich.

9-12 Productus parvus. Meek and Worthen. Nos. 9-11, Chester, Ill. No. 12, the so-called Pella beds, Pella, Iowa. (Ste. Genevieve limestone.) Seems to be mainly a Fredonia species in Kentucky. See Ulrich's lists, this volume. After Weller.

13 Group of specimens of Cystelasma rugosum. Ulrich. A coral. Fredonia oolite. After Ulrich.

14 Group of specimens of Cystelasma quinqueseptatum. Ulrich. Fredonia oolite. After Ulrich.

15 Group of specimens of Lithostrotion harmodites. Edwards and Haime. A coral. Fredonia oolite. After Ulrich.

16 Group of specimens of Amplexus geniculatus. Worthen. A coral having a sharp flexure as shown in two specimens. So far as known restricted to the Ohara member in western Kentucky and southern Illinois. Occurs in the shale bed No. 3 of the section.

17 Group of specimens of Pentremites princetonensis. Ulrich. Small form most commonly occurring in the Fredonia oolite of Breckinridge County. Has usually been identified as P. florealis. After Ulrich.

18 Michelinia princetonensis. Ulrich. A coral. Fredonia oolite. After Ulrich.

19-20 Michelinia subramosa, Ulrich. A coral. Fredonia oolite. After Ulrich.

21-24 Pugnoides ottumwa. (White.) Ste. Genevieve limestone, Fredonia member, at Bowling Green and in Breckinridge County. Not common. Specimens from Ste. Genevieve limestone at Fountain Creek, near Waterloo, Ill. After Weller.

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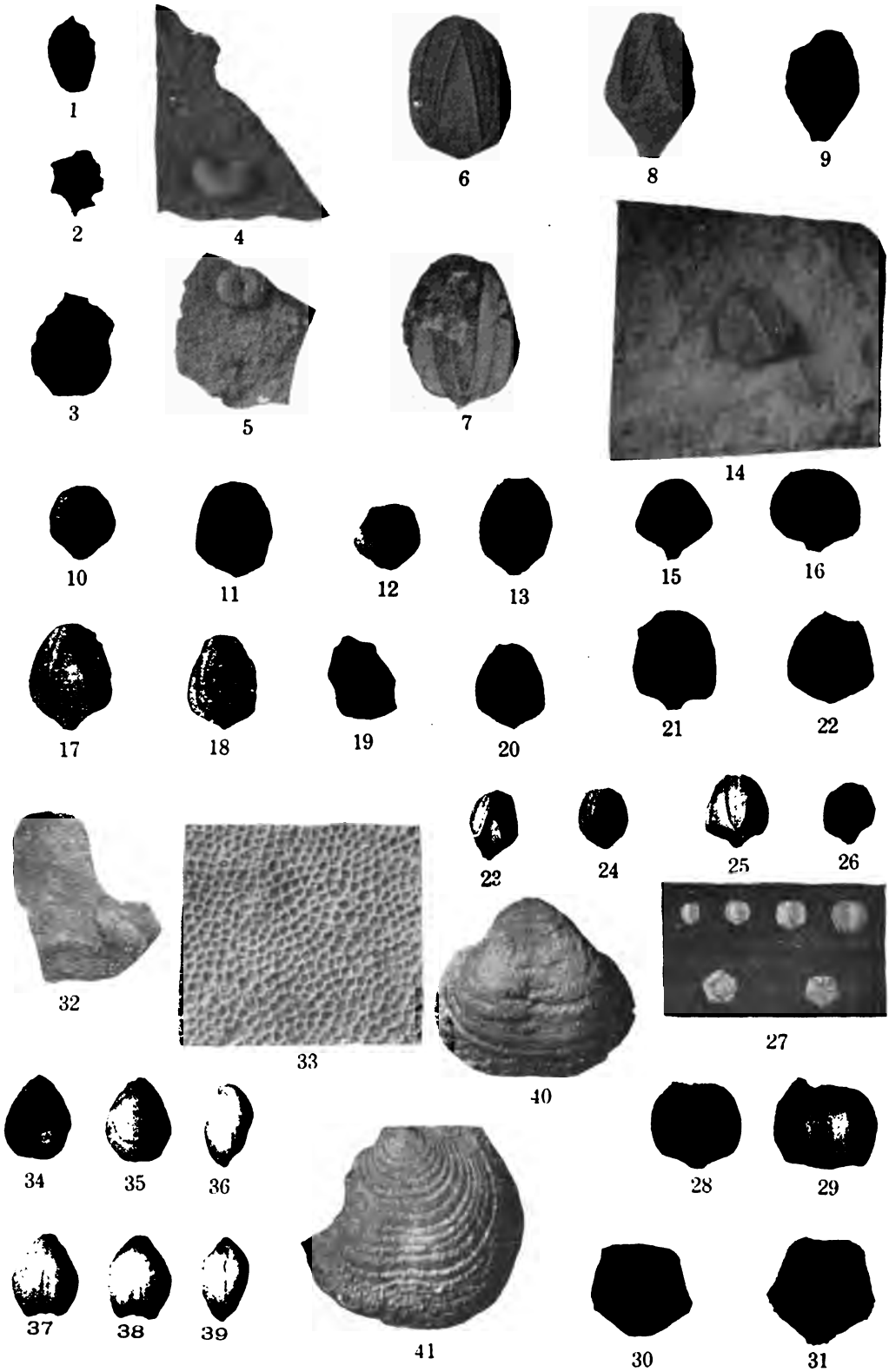

PLATE 15.

Fossils from the Ohara member of the Ste. Genevieve limestone and other formations.

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The lower part of the Ohara member or lower Ohara is not usually very fossiliferous, and no material has been obtained from it in the course of this work. *Platycrinus huntsvillae* occurs in it throughout and was observed wherever the beds were exposed from Princeton, Ky., to Rosiclare, Ill.

The upper part of the Ohara member of the Ste. Genevieve limestone (upper Ohara) is abundantly fossiliferous and numerous collections have been made from it, especially in Caldwell and Crittenden counties. These fossils have been exhaustively studied by Ulrich and the reader is referred to his lists in his paper in this volume.

The most important fossils from the standpoint of correlation are several species and varieties of the genera Pentremites and Talarocrinus. A few of these forms along with others less characteristic of the Ohara are illustrated on Plate 15.

FOSSILS FROM THE OHARA LIMESTONE MEMBER OF THE STE. GENEVIEVE LIMESTONE AND OTHER FORMATIONS.

Plate 15.

1-2 Talarocrinus sp. Shale bed, No. 3, of Ohara limestone member. Bridge crossing Muddy Fork of Little River about 2 miles north of Cerulean, Trigg County, Ky.

3-5 Talarocrinus sp. trijugis; Miller. Cherty limestone bed, No. 4 of the Ohara. No. 3, a nearly complete head without the arms from shore of Ohio River just above low water level a short distance above the mouth of Grand Pierre Creek, Pope County, Ill. No. 4, one of the two basal plates from Ridenhower, Ill. No. 5, both basal plates from about midway between Craneyville and View, Crittenden County, Ky. These basal plates are the parts of Talarocrinus most commonly seen. So far as known the genus Talarocrinus is almost exclusively confined to the Ohara member of the Ste. Genevieve limestone and to the Gasper oolite, according to Ulrich the Ohara and Gasper species being distinct. (See his paper this volume.)

6-7 Pentremites ovoides. Ulrich. n. sp. Top cherty limestone, No. 4 of Ohara. Midway between Carrsville and Deer Creek, Livingston County, Ky.

8-9 Pentremites buttsi. Ulrich. n. sp. Top cherty limestone, No. 4 of Ohara.

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10-26 Pentremites princetonensis and varieties. Ulrich. n. sp. Ohara shaly bed, No. 3, and cherty limestone bed No. 4, mostly from the last named. 10-13, top bed of Ohara, Ridenhower, Ill. 14, shaly bed of Ohara No. 3. Midway between Carrsville and Deer Creek, Livingston County, Ky. 15, 16, 21, and 22, top cherty limestone, No. 4 of Ohara. Midway between Craneyville and View. 17, top cherty limestone, No. 4 of Ohara, Downeys Bluff, Rosiclare, Hardin County, Ill. 18-20, 23-26, top cherty bed, No. 4 of Ohara. Midway between Carrsville and Deer Creek.

27-31 Mesoblastus glaber. Meek and Worthen. After Ulrich. Shale bed, No. 4 of Ohara. Crooked Creek about 2 miles northwest of Marion, Crittenden County, Ky. 27, natural size. 28-31, enlarged three times. This or scarcely distinguishable forms range from St. Louis to Gasper limestones but rare except in bed No. 3 of the Ohara member of the Ste. Genevieve limestone.

32-33 Stenopora tuberculata. Ulrich. Shale bed of Ohara where it is common at all localities. Midway between Carrsville and Deer Creek, Livingston County, Ky. 32, natural size; 33, enlarged six times. Ranges through the Meramec and Chester groups.

34-36 Girtyella indianensis. (Girty.) After Weller. Ste. Genevieve to middle Chester. Abundant in Ohara and Gasper, especially so in the shale bed of the Ohara and the lower part of the Gasper.

37-39 Girtyella brevilobata. (Swallow.) About the same range as Girtyella indianensis. After Weller.

40-41 Echinochonchus (Pustula) Genevievensis. Weller. Fredonia and Ohara members of the Ste. Genevieve limestone. Fairly common in the upper Ohara. After Weller.

CHESTER GROUP (IN WHOLE OR IN PART).

Exclusive of the Ste. Genevieve Limestone, the grouping of which is still in dispute, some authors including it in the Chester group and other authors excluding it from that group, the Chester rocks in this area are divisible into several formations, as shown in the correlation charts forming Plates 2 and 3 and as described on the following pages.

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BETHEL SANDSTONE.

The name Bethel is here introduced for the sandstone overlying the Ohara limestone member, the lower part of the sandstone being especially thick and well displayed in the vicinity of Bethel school, 3½ miles west of Marion, Crittenden County, Ky. This is the Cypress sandstone of Ulrich in Professional Paper 36 of the United States Geological Survey entitled, "The lead, zinc, and fluorspar deposits of western Kentucky." Owing, however, to the fact that this sandstone is now known to be an older and lower stratum than the true Cypress sandstone, the use of the name Cypress for it must be abandoned.

There is probably a slight unconformity between the Bethel sandstone and the Ohara member. This belief is based on the fact that in places the sandstone lies in contact with the persistent fossiliferous shale segment in the upper part of the Ohara, and in places is separated from the shale by a varying thickness of limestone, which, in the Downys Bluff section, Section No. 2, Plate 3, is as much as 40 feet.

The Bethel is generally a thick-bedded, rather coarse-grained standstone. In some sections it seems to be prevailingly flaggy. At Downys Bluff in Hardin County, Ill., at Bethel school, and probably at other points in the same region there are a few small quartz pebbles in the lower part of the sandstone. This is the only sandstone of the Chester group so far as the writer is aware in which pebbles occur, and in this the pebbles are too few to constitute a conglomerate or to warrant its characterization as conglomeratic.

The Bethel sandstone is present and about 10 feet thick, about one-third of a mile north of Fairview near the line between Christian and Todd counties, Ky., but has not been observed farther east. Westward it thickens to 40 feet or so at Hopkinsville, and with the greater thickness becomes able to affect the topography so that it caps a bench 100 feet or more above the general level of the Fredonia oolite surface. The massive sandstone about 30 feet thick on Wallace Creek north of Cerulean and near Muddy Fork of Little River is Bethel. Just north of Bethel school, it is fully 100 feet in thickness,

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thick-bedded, and coarse-grained. It makes the cliff on the west side of Ohio River south of Shetterville, Ill. It dips southward and is beneath the river at Golconda whence it rises southward, its top appearing from below the river about one-half mile south of Golconda. The southward rise continues and 3 miles or so south of Golconda the Bethel sandstone froms a cliff estimated to be 60 feet high, the base of which is about 30 feet above the river at low water.

The Bethel, like the other Chester sandstones, generally is destitute of fossils except possibly a few plant remains.

The correlation of the Bethel sandstone will be discussed in connection with the discussion of the correlation of the Ohara limestone and Gasper oolite on succeeding pages.

GASPER OOLITE.

CHARACTER AND OCCURRENCE.—The name Gasper oolite is here introduced as a substitute for Ulrich's name Tribune limestone, the latter name having been applied by Ulrich through a misapprehension as explained in the note below.* The name is from Gasper River in Warren County along the bluffs of which the oolite is excellently developed and exposed.

The Gasper oolite outcrops from Ohio River in the vicinity of Richardsons Landing southward and westward to eastern Caldwell County in a band paralleling in a general way the margin of the coal field. It is exposed in the top of the old quarry one-half mile west of Richardsons Landing, along the railroad about 1 mile east of Sample station in Breckinridge County (See Plate 16); in the oolite quarries in the vicinity of Bowling Green, and on the Princeton-Hopkinsville pike in Christian County, about 1 mile east of the county line. This last mentioned locality furnished the type section of Ulrich's Tribune limestone, here called the Gasper

*In Professional Paper 36 of the United States Geological Survey, "The lead, zinc, and fluorspar deposits of western Kentucky," the name Tribune was applied to this limestone and oolite from the hamlet of Tribune in the eastern part of Crittenden County. The name was used because it was believed that the limestone excellently exposed at Tribune is the same as the limestone or oolite to which the name Gasper is here applied. It is now known that the limestone at Tribune is the Menard limestone, occupying a higher position in the stratigraphic series than the Gasper oolite, as shown by the sections on Plate 3 of this report.

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Sample S. S. 25 feet exposed.

Contact.

Limestone 3 feet.

Shale 5 feet.

Compact limestone, partly oolite, 20 feet.

Shale. Talarocrinus patei, abundant. See Plate 21, Figs. 24-26.

PLATE 16.

Photograph of cut on the Louisville, Henderson & St. Louis railroad about about 1 mile east of Sample, Breckinridge County, Ky. Showing Sample sandstone member at the top and the lower part of the Gasper oolite below with two thin shale beds from which many fine specimens of Talarocrinus patei have been collected.

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PLATE 17.

Photograph looking east from the brink of the upland terrace on the highway about 1 mile north of Fairview, Todd County. The high ground in the distance is a salient of the extensive terrace capped by the Cypress sandstone visible from the Louisville & Nashville Railroad for so much of the distance between Munfordville and Bowling Green. Bluff below terrace level mainly occupied by the outcrop of the Gasper oolite and plain to right is developed upon the Ste. Genevieve limestone.

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oolite. The so-called Bowling Green oolite, a building stone of excellent qualities, is obtained from the Gasper oolite at several quarries on Barren River and Gasper River north and west of Bowling Green.

The Gasper forms the face of the bluff which is so conspicuous a feature, visible from the Louisville & Nashville Railroad for several stretches aggregating many miles along its course between Russellville and Elizabethtown. This bluff is the edge of a broad upland terrace capped by the Cypress sandstone next to be described. (See Plate 17.)

The Gasper oolite is composed of thick-bedded limestone and oolite and in parts of Breckinridge County includes near the middle the Sample sandstone member 40 feet thick as a maximum. The oolite is the most characteristic part of the formation. North of Bowling Green a 20-foot segment of coarse, massively bedded oolite lies about 50 feet below the bottom of the Cypress sandstone. This oolite is made up almost wholly of large oolitic bodies, the great majority of which are, judging from the size of those in samples from other localities, about .7 millimeter in diameter. The rock is of rather soft texture and splits freely, the fractures passing around many of the oolite bodies which stand out conspicuously on the broken surfaces. (See Plate 18.) Coarse oolite of like character is a large constituent of the Gasper west of Bowling Green to Caldwell County,

PLATE 18.

Piece of oolite from 3-foot layer in the upper part of the Gasper oolite at Sample, Breckinridge County, Ky. This is from the horizon of the oolitic quarry-rock at Bowling Green.

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and a bed of white oolite, possibly the same as that at Bowling Green described above, persists northward to Breckinridge County. In the section north of Sample (See Section 28, Plate 3.) is 3 feet of coarse oolite 30 feet below the top of the Gasper. A photograph of a piece of weathered oolite from this exposure is shown in Plate 18.

A white oolite bed is present in other sections in about the same stratigraphic position, which is that of the quarry bed in the Bowling Green quarries, as at Russellville, northwest of Smith's Grove, and northwest of Munfordville. (See sections of Plate 3.) The rest of the Gasper, besides the prominent oolites and the sandstone member described below, is rather thick-bedded limestone and compact oolite. In some of the sections in Christian and Caldwell counties the larger part of the thickness is thick-bedded oolite which is of more compact character than the Bowling Green quarry bed. In Breckinridge County most of the Gasper is not conspicuously oolitic, but on close examination a considerable proportion of the compact, dove colored layers are found to be oolitic and similar to the layers of compact oolite in the Fredonia member of the Ste. Genevieve limestone which is the only part of the Ste. Genevieve limestone in Breckinridge County.

At the bottom of the Gasper at several points in Breckinridge County is a bed of dark gray siliceous oolite about 5 ft. thick in which the silica is in the form of fine quartz grains quite uniformly .1 millimeter in diameter, scattered evenly through the mass and making up perhaps one-tenth of the same. Beneath the siliceous oolite is a layer 2 feet or so thick containing a considerable number of rounded pebbles of oolitic limestone and beneath the latter there is in the railroad cut 1 mile east of Sample a coarse dark gray oolite regarded as the top of the Ste. Genevieve limestone. The siliceous and pebbly layers are both present and exposed in a quarry on the Fordsville branch of the Louisville, Henderson & St. Louis Railroad, about 1 mile south of Sinking Creek and in a cut a little farther south, and the siliceous layer is present on the knob 1 mile south of Irvington. This layer is identical in appearance and composition with the one in the Cedar Bluff quarry southeast of

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Princeton. However, the fossils above the simulating beds in the two places are not the same and according to Ulrich clearly indicate that they are of different ages.

A few feet above the bottom of the Gasper in the railroad cut 1 mile east of Sample are two layers of shale, the upper 8 inches and the lower 2 feet thick. (See section 29, Plate 3 and Plate 16.) These shale layers are profusely fossiliferous and are the source of many of the fossils listed, including the Talarocrinus. Many fine specimens of *Talarocrinus patei* preserving the arms have been obtained from nests in one of these shale layers. The fine specimen figured in Plate 21, Figures 24 and 26, were obtained here. A shale or clay bed 2 to 3 feet thick is present in several sections from Munfordville to Caldwell County. This clay will be reverted to in the following description of the Sample sandstone member. In the section east of Sample also a shale bed 5 to 7 feet thick, including a 1-foot layer of coarse gnarly yellow asphaltic sandstone, occurs 3 feet below the top of the Gasper.

In Christian County, Ky., east of Hopkinsville and north of Fairview, particularly in the neighborhood of Honey Grove church, a considerable body of shale, 10 to 30 feet thick, lies between the Gasper oolite and the overlying Cypress sandstone. This shale is present in the section north of Elkton in Todd County and in that on the Princeton-Hopkinsville pike in western Christian County. (See Sections 5, 9 and 10, Plate 3.) In the highway about 1 mile eastward from Honey Grove it is partly red and apparently thicker than elsewhere. Possibly this shale represents the thinned eastward edge of the Ridenhower shale to be described.

As already mentioned, the Gasper 3 miles or so northward from Bowling Green, includes a 20-foot bed of coarse white oolite that is an excellent building stone. While, according to accounts, the freshly quarried and laid stone is somewhat stained dark by bituminous substance, that in a short time evaporates and leaves the stone nearly white. This stone receives the highest praise from competent authorities for color, texture, strength, durability, ease of working, and resistance to discoloration and heat. So far as developments have proceeded this oolitic bed is of high grade from Bowling

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Green westward to the mouth of Gasper River and southward on Gasper River. The bed is said to have 200 miles of outcrop in Warren County. As set forth in the preceding pages the Gasper oolite 100 feet or more thick, extends both west and northwest from Warren County and has oolite similar to that of the quarry bed north of Bowling Green. It is not unlikely that good building stone will be found beyond the limits of Warren County.

The Gasper oolite so far as analyzed is of a high degree of purity and excellently adapted to agricultural and industrial uses, such as for lime and cement. The white oolite is said to make a non-discoloring cement which is in great demand.*

SAMPLE SANDSTONE MEMBER.—In Breckinridge, Meade, Hardin, Grayson counties, and perhaps in Hart

PLATE 19A.
Sample sandstone member, massive phase. Bluff above railroad about 1 mile east of Sample.

*For an account of this stone see, "The oolitic limestones of Warren County," by Malcolm H. Crump: Kentucky Geol. Survey, 4th Ser., Vol. 1, pt. 2, 1913.

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County, a sandstone stratum is present in the Gasper oolite. This is named the Sample sandstone member, from its strong development and good exposures east of Sample station in Breckinridge County on the Louisville, Henderson & St. Louis Railroad. Here, 1 mile east of Sample, it reaches a thickness of 40 feet of massively bedded sandstone. (See photos, Plates 16, 19, and 20.) Although partly hidden by the trees the massive character of the Sample sandstone is plainly exhibited in the photograph. In a railroad cut a little farther east the lower 25 feet of the Sample is fully exposed. (See Plate 16.) Here the lower part is evenly thick-bedded while the upper part is cross-bedded. It is here all medium coarse-grained siliceous sandstone.

The Sample sandstone varies greatly in character and thickness in short distances. For example, in the highway immediately north of Sample it consists of 5 feet of sandstone overlain by 15 feet of coarse, sandy, mealy shale with a few fossils, while on a low knob one-fourth of a mile south of Sample it is a coarse, thick bedded sandstone occupying the upper 25 feet of the knob and its full thickness is unknown. On the Fordsville branch of the Louisville, Henderson and St. Louis Railroad about 1½ miles south of Sinking Creek, the Sample is partly shale and partly flaggy sandstone, the

PLATE 19B.

Cut on the Fordsville Branch of the Louisville, Henderson & St. Louis railroad, about 1½ miles south of Sinking Creek, showing the Sample sandstone member changed partly to shale with an unconformity between the shale and sandstone.

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shale overlying the sandstone. Between them is an angular unconformity indicating considerable local erosion previous to the deposition of the shale. These features are exhibited in the photograph, Plate 19-B.

Near East View in Hardin County, 20 miles southeast of the point last described the Sample sandstone has degnerated to about 20 feet of shale and flaggy sandstone as shown in Plate 20. Farther south, in a section about 5 miles northwest of Munfordville, is a shale layer on the outcrop of which at one point a few thin chips of sandstone were lying. It is believed that this represents the horizon of the Sample sandstone member. A clay bed in the same position is present northwest of Smith's Grove, at the Victoria quarry north of Bowling Green, and at the fine exposure (Ulrich's type locality of the "Tribune limestone") on the Princeton-Hopkinsville pike in the western part of Christian County. Here the clay is 2 to 3 feet thick and lies at the

PLATE 20.

Photograph of the Sample sandstone member of the Gasper oolite in a cut on the Illinois Central Railroad, about one-half mile north of East View, Hardin County, Ky. Shows the Sample sandstone breaking down into shale.

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road level, the road bed being on the limestone layer on which the clay bed rests. While this clay bed appears to lie at the horizon of the Sample sandstone member, it has not been established beyond doubt that such is the fact. This subject is further discussed in connection with the discussion of the general correlation of the Ohara member of the Ste. Genevieve limestone, the Bethel sandstone, and the Gasper oolite.

RIDENHOWER SHALE.

The name Ridenhower, from Ridenhower, Ill., is applied to a predominantly shale formation between the Bethel and Cypress sandstones in Crittenden and Livingston counties, Ky., and in southern Illinois.

The Gasper oolite is not known west of the eastern part of Crittenden County. On the Princeton-Hopkinsville pike, in the western part of Christian County, is located the exposure which Ulrich adopted as the type of his "Tribune limestone" as hereinbefore described. Somewhat farther northeast, on the Illinois Central Railroad midway between Scottsburg and Claxton, Ulrich identified as "Tribune" the limestone of another exposure in a railroad cut known as Lambs cut. Northeastward from this region the continuity and sequence of outcrops are interrupted by a number of faults and in this faulted country the Gasper oolite has been identified only in the eastern part of Crittenden County about 2 miles south of Craneyville. The Bethel sandstone, however, below the Gasper in Christian and Caldwell counties can be surely identified across this faulted territory, and likewise the Cypress sandstone next above the Gasper. Between the Bethel and Cypress in Crittenden County, Ky., in Pope and Hardin counties, Ill., and below the Cypress sandstone at Ridenhower, Johnson County, Ill., is a stratum of shale or of shale, thin sandstone, and of thin sandy limestone 50 to 60 feet thick. Because of its occurrence at Ridenhower this shale at the suggestion of Stuart Weller is named the Ridenhower shale. In Crittenden County, Ky., the Ridenhower shale facies, probably equivalent to the upper part of the Gasper oolite, is known to make its appearance in the section at least as far south as a point 1½

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miles west of Craneyville, where immediately above the Bethel sandstone is exposed a few feet of shale and sandy limestone full of fragmentary fossils. The banks for 50 feet immediately above this exposure indicate soft rocks probably predominantly shale. This shale is overlain by a thick and massive development of the Cypress sandstone. The change from the Gasper to the Ridenhower facies is completed apparently between a point 2 miles south of Craneyville where Ulrich observed typical Gasper and the locality 1½ miles west of Craneyville where the writer observed the basal shaly facies just described.

Inasmuch as the Ridenhower shale occupies the same stratigraphic postion as the Gasper oolite, that is the interval between the Bethel and Cypress sandstones, it is regarded as equivalent in part at least to the Gasper oolite. Possibly, however, it represents only the shale at the top of the Gasper in Christian County, Ky., etc.

Owing to the faulted character of the country and to the consequent lack of a sufficient number of closely spaced exposures between the most northwestern exposures of the typical Gasper oolite in its full thickness and the nearest known complete exposure of the Ridenhower shale still farther to the northwest in the vicinity of Marion, it is impossible to trace the two facies of the rocks between the Bethel and Cypress sandstones and to determine by actual observation just what their stratigraphic relations are—whether the one passes into the other laterally or whether the relation is that of overlap of the shale upon the oolite, making in that case, the shale a later deposit than the limestone.

The Ridenhower shale in Ohio Valley and western Kentucky is almost wholly a soft dark clay shale weathering to a bluish or greenish tint. Besides shale a very little thin ferruginous and in places calcareous sandstone or sandy limestone is present. A good exposure of the shale in the condition of laminated clay, which is the result of weathering, occurs on the road to Siloam school at a point 3 miles west-southwest of Marion in Crittenden County. Here the full thickness of 50 feet or so is exposed in the road ditch with the bounding sandstones exposed above and below. A few thin ferruginous sandstone chips were obtained from the

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outcrop here. These have some obscure small fossils not determinable. On the river bluff about one-half mile below Golconda, Ill., the shale 50 feet thick, is fully exposed between the Bethel and Cypress sandstones. Here somewhat below the middle are a few thin calcareous sandstone layers with fossils as listed on another page. Where exposed in stream beds in Pope and Hardin counties, Ill., the shale is dark or nearly black in color. That seems to be the normal color of the fresh shale.

Owing to its being a soft stratum between two sandstones, exposures of the Ridenhower shale are few and far between. It has been seen by the writer in only four places in a circuit from Golconda through eastern Pope and western and northern Hardin counties, Ill., to the exposure above mentioned, 3 miles southwest of Marion, Ky., but its presence is almost everywhere expressed in the topography by a shallow depression in the land surface between the outcrops of the inclosing sandstone strata.

At Ridenhower the shale is 60 feet thick and includes considerable limestone which is fairly fossiliferous. The Ridenhower is fairly fossiliferous at Ridenhower, Ill., much less so at Golconda, while in the vicinity of Marion hardly a trace of a fossil could be found. Lists from Ridenhower and Golconda are given below:

FAUNA OF THE RIDENHOWER SHALE FROM RIDENHOWER, ILL.

Cystelasma aff. tabulatum.
Protopora? sp.
Pentremites pyramidatus. Ulrich.
Pentremites godoni? Defrance.
Pterotocrinus depressus. Lyon and Casseday.
Fistulipora sp.
Stenopora sp.
Fenestella sev. sp.
Polypora sp.
Archimedes distans. Ulrich.
Archimedes invaginatus? Ulrich.
Archimedes confertus. Ulrich.
Archimedes compactus. Ulrich.
Archimedes proutanus. Ulrich.
Septopora subquadrans. Ulrich.
Lyropora quincunxialis. Hall.
Glyptopora sp.

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Cystodictya pustulosa. Ulrich.
Rhombopora sp.
Orthotetes kaskaskiensis. (McChesney.)
Productus ovatus. Hall.
Diaphragmus elegans. (Norwood and Pratten.)
Girtyella indianensis? (Girty.)
Spirifer increbescens. Hall.
Reticularia setigera. (Hall.)
Spiriferina spinosa. Norwood and Pratten.
Composita trinuclea. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria verneuiliana. (Hall.)
Aviculipecten sp.
Leptodesma sp.
Myalina aff. sanctiludovici. Worthen.
Chiton sp.
Griffithides sp.

FOSSILS OF THE RIDENHOWER SHALE ON BLUFF OF OHIO RIVER ONE-HALF MILE SOUTH OF GOLCONDA.

Fenestella sev. sp.
Archimedes sp.
Cystodictya labiosa. Ulrich?
Glyptopora cf. punctipora. Ulrich.
Chonetes cf. chesterensis. Weller.
Girtyella indianensis. (Girty.)
Spirifernia spinosa. (Norwood and Pratten.)
Eumetria vera. (Hall.)
Leda sp.
Aviculipecten sp.
Gastropods, several small undetermined species.
Phillipsia sp.

The Gasper is a highly fossiliferous formation and a long list from it in western Kentucky is given by Ulrich, this volume. A list made up from collections of the writer obtained in Breckinridge County and smaller collections by the writer and others at various localities between Breckinridge and Caldwell counties is given below.

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FAUNA OF THE GASPER OOLITE—CHIEFLY FROM NON-OOLITIC BEDS.

The collections listed below are mainly from Breckinridge County:

Syringopora sp.
Triplophyllum spinulosum. Edwards and Haime.
Campophyllum n. sp.
Thysanophyllum sp.
Talarocrinus simplex. Shumard.
Talarocrinus cornigerus. (Shumard.)
Talarocrinus symmetricus. Lyon and Casseday.
Talarocrinus patei. Miller and Gurley.
Agassizocrinus sp.
Pentremites pyriformis. Say.
Pentremites pyramidatus. Ulrich.
Pentremites godoni. Defrance.
Pentremites sulcatus. Roemer.
Ortonia sp.
Spirorbis sp.
Fistulipora sp.
Stenopora sp.
Batostomella sp.
Fenestella sev. sp.
Polypora sp.
Archimedes confertus? Ulrich.
Archimedes meekanus. Hall.
Archimedes laxus. Hall.
Lyropora quincunxialis. Hall.
Glyptopora n. sp.
Cystodictya pustulosa? Ulrich.
Streblotrypa nicklesi. Ulrich.
Orthotetes kaskaskiensis. (McChesney.)
Chonetes sericeus?
Productus inflatus. McChesney.
Productus adairensis.
Productus arkansanus.
Productus ovatus. Hall.
Diaphragmus elegans. (Norwood and Pratten.)
Pustula (Echmolonchus) alternata? (Norwood and Pratten.)
Girtyella indianensis. (Girty.)
Girtyella turgida. (Hall.)
Girtyella brevilobata. (Swallow.)
Dielasma illinoisense. Weller.
Camarophoria explanata. (McChesney.)
Spiriferina transversa. (McChesney.)
Spiriferina spinosa. (Norwood and Pratten.)

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Spirifer aff. pellensis. Weller.
Spirifer leidyi? Norwood and Pratten.
Reticularia setigera. (Hall.)
Martinia sulcata? Weller.
Brachythyris ozarkensis?
Composita subquadrata. (Hall.)
Composita trinuclea. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria vera. (Hall.)
Eumetria verneuiliana. (Hall.)
Allerisma sinuatum? McChesney.
Sphenotus sp.
Parallelodon micronema.
Nucula? sp.
Deltopecten sp.
Laevidentalium venustum.
Bellerophon sublevis? Hall.
Phanerotrema sp.
Naticopsis n. sp.
Euomphalus planidorsatus? Worthen.
Zygopleura n. sp.
Platyceras sp.
Coelonantilus sp.
Griffithides sp.
Paraparchites sp.
Primitia sp.

GASPER OOLITE AND OTHER FOSSILS.

Plate 21.

1-3 Spirifer pellaensis. Weller. Fredonia oolite to Gasper oolite. (After Weller.)
4-6 Spirifer leidyi. Norwood and Pratten. Same range as Sp. pellaensis with which it is associated and from which it is with difficulty distinguished. (After Weller.)
7-9 Productus inflatus. McChesney. Fredonia oolite to top of Gasper oolite. After Weller.
10-13 Chonetes chesterensis. Weller. From Paint Creek limestone, Randolph County, Ill. The same or similar species occurs in the top and bottom of the Gasper oolite associated with Productus inflatus. After Weller.
14-17 Pentremites pyriformis. Say. Common in the Gasper oolite to which it appears to be confined in Kentucky and Illinois.
18-19 Pentremites godoni var. biconvexi. Ulrich n. var. After Ulrich. Differs from P. godoni by having biconvex ambulacral areas.
20-23 Pentremites godoni. Defrance. Regarded as confined to the

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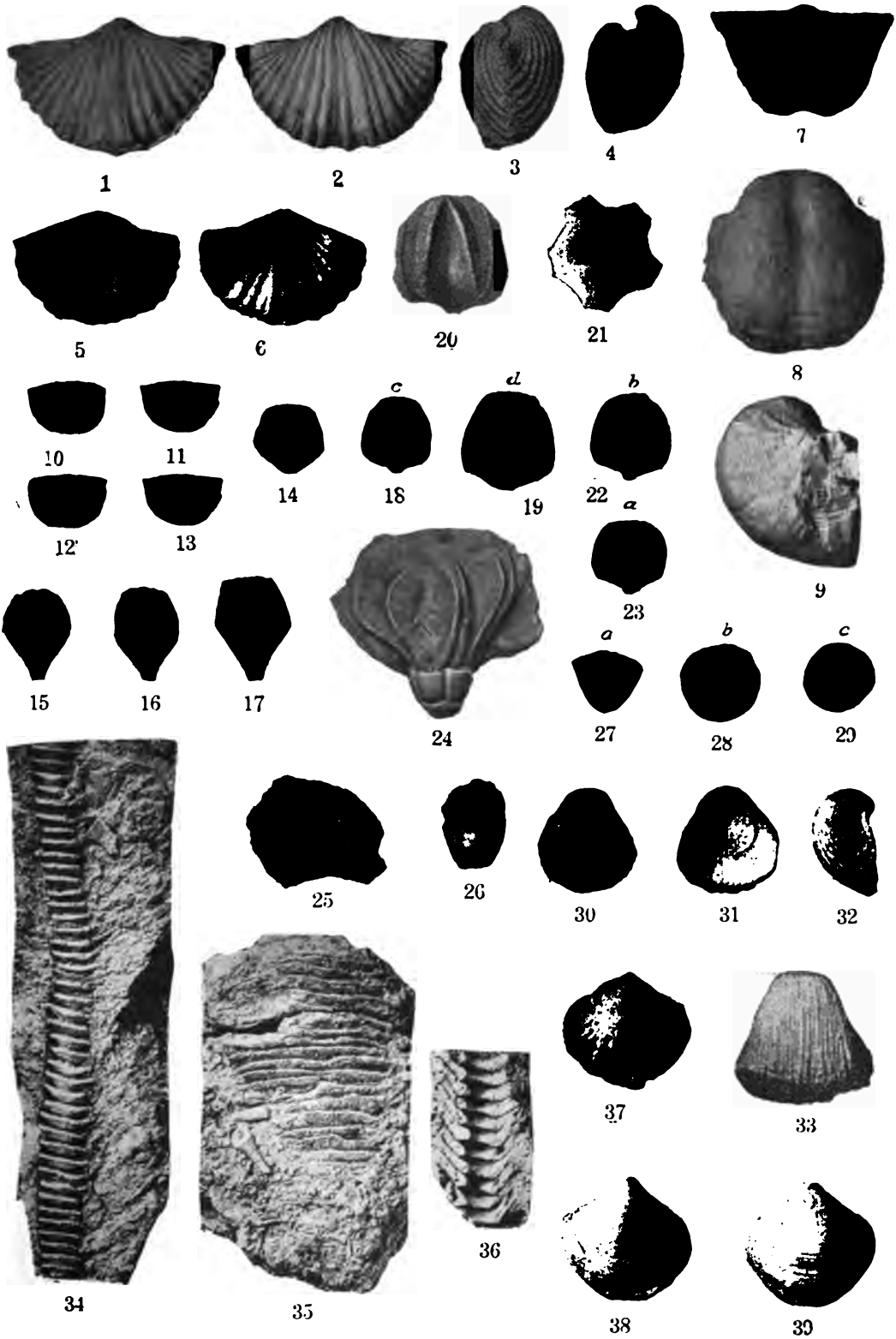

PLATE 21.

Fossils from Gasper oolite and other formations.

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Gasper oolite in Kentucky and Illinois. Differs from princetonensis in the deeply sulcate ambulacral areas. The deep angular ambulacral furrow is best shown in figure 20 on the right of figures 22 and 23. After Ulrich.

24-26 Talarocrinus patei. Gasper oolite below Sample sandstone in Breckinridge and Hardin counties, Ky. No. 24, a complete specimen showing base, radial plates, and arms. No. 26, a complete head without the arms. Both specimens from shale layer in the bottom of the Gasper in one of the railroad cuts 1 mile east of Sample, Breckinridge County. (See Plate 16.) No. 25 shows base and radial plates. About 1 mile southwest of Stephensburg, Hardin County, Ill. This or the two basal plates, either separate or together, projecting from the face of the solid limestone layers, is the most common mode of occurrence. These can be found in both the upper and lower parts of the Gasper oolite throughout western Kentucky. The genus is nearly restricted to the Ohara and Gasper of Kentucky and to the Renault and Paint Creek formations of the Mississippi Valley. Figures 24 and 26 by courtesy of Mr. Frank Springer.

27-29 Agassizocrinus conicus. Owen and Shumard. Gasper and overlying Chester formations, especially in the Glen Dean. Very rare below the Glen Dean, if the form occurring below is indeed this species. After Ulrich.

30-33 Diaphragmus (Productus) elegans. (Norwood and Pratten.) Begins in the Fredonia oolite and extends to the top of the Chester throughout which it is abundant. After Weller.

34-36 Archimedes confertus. Ulrich. Sandy layers in the top of the Gasper oolite or bottom of the Cypress sandstone, to which—so far as known—it is limited in western Kentucky and southeastern Illinois. Distinguished by its closely spaced spiral frond. On specimen 35 is a broken spine of the crinoid genus Hydreionocrinus common in the Gasper oolite of western Kentucky. After Ulrich.

37-39 Cliothyndina sublamellosa. (Hall.) Common Chester species. No. 37 shows the flat spines with which the shell was covered in life. In 38 and 39 the spines have been broken off in fossilication. After Weller.

The Gasper is notable for the great number of peculiar species of Pentremites as listed by Ulrich. A few of these are illustrated on Plate 21. Besides these the species of Talarocrinus listed and figured are characteristic. The genus is not known above the Gasper. Another form that becomes common in the Gasper is *Agassizocrinus conicus* or a similar species. Specimens of this

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genus seem unknown in the Ohara and only a comparatively few specimens seem to have been found in the Fredonia oolite member of the Ste. Genevieve. A number of the forms listed is illustrated on Plate 21.

According to Girty, "the faunas of the oolitic rocks of the Gasper resemble the faunas of those that are not oolitic, except that in the former molluscan forms predominate over the molluscoidean, and in the latter molluscoidean forms predominate over the molluscan. The following list will give a fairly accurate idea of the oolitic faunal phrase. It represents a single collection from a strongly oolitic bed within a few feet below the top of Gasper oolite in the western edge of Christian County. This is the section on which Mr. Ulrich's description of the 'Tribune limestone,' was chiefly based. Many of the identifications in this list are open to question, for not only has this fauna never been carefully studied and described but the fossils from this locality are more or less covered with a calcareous deposit which conceals their specific characters."

Many of the forms are of small size and are the same species or slight variations thereof as occurs also in the oolitic beds of the Spergen limestone, in the Fredonia oolite member of the Ste. Genevieve limestone, and in the oolitic beds of the Okaw formation of southwestern Illinois. This dwarf fauna in fact flourished under the conditions under which oolites were deposited and reinvaded the Mississippian Valley region whenever oolitic forming conditions recurred, going elsewhere at other times. It is known as the recurrent Spergen fauna, having made its first appearance in the general region at the time of the deposition of the Spergen limestone.

FAUNA OF THE GASPER OOLITE FROM AN OOLITIC BED NEAR THE TOP IN THE WESTERN EDGE OF CHRISTIAN COUNTY.

Triplophyllum sp.
Pentremites pyriformis?
Crinoid undet.
Fistulipora sp.
Fistulipora? sp.
Meekopora? sp.
Glyptopora sp.
Stenopora sp.

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Batostomella sp.
Fenestella sev. sp.
Polypora sp.
Septopora sp.
Archimedes sp.
Cystodictya sp.
Crania? sp.
Schuchertella sp.
Diaphragmus elegans.
Girtyella turgida.
Spiriferina transversa.
Spirifer pellensis var.
Composita trinuclea?
Cliothyridina sublamellosa.
Eumetria verneuiliana.
Edmondia genevievensis?
Sphenotus aff. rigidus.
Sphenotus aff. rigidus var.
Sphenotus aff. octoplicatus.
Parallelodon aff. obsoletum.
Parallelodon micronema?
Parallelodon aff. minima.
Cypricardina indianensis.
Leda aff. bellistriata.
Nucula illinoisensis?
Aviculipecten aff. herzeri.
Aviculipecten sp.
Pteria aff. sulcata.
Leptodesma aff. spergenensis.
Caneyella hopkinsi?
Conocardium sp.
Myalina elongata?
Cypricardella subelliptica?
Schizodus depressus?
Laevidentalium venustum.
Bellerophon aff. sublevis.
Bucanopsis textilis?
Euphemus sp.
Pleurotomaria aff. subglobosa.
Pleurotomaria sp.
Phanerotrema? sp.
Solenospira aff. pygmaea.
Solenospira aff. illinoisensis.
Solenospira aff. turritella.
Zygopleura n. sp.
Zygopleura aff. wortheni.
Loxonema? sp.

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Eotrochus sp.
Naticopsis aff. carleyana.
Holopea aff. proutana.
Straparollus spergenensis?
Bulimorpha? sp.
Ptychomphalus wortheni?
Cyclonema globosum?
Cyrtoceras? aff. ashmani.
Stroboceras sp.
Phillipsia sp.
Bollia? sp.

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CORRELATION OF THE OHARA LIMESTONE MEMBER OF THE STE. GENEVIEVE LIMESTONE, THE BETHEL SANDSTONE, AND THE GASPER OOLITE.

The Fredonia oolite member of the Ste. Genevieve limestone is, in Breckinridge County and that general region of Kentucky, in unconformable contact with the Gasper oolite through the absence of the Rosiclare and Ohara members of the Ste. Genevieve limestone and of the Bethel sandstone. This determination is based upon the fact that the Gasper is immediately underlain by about 160 feet of limestone with thick strata of oolite of typical Fredonia character and the fact that in places, as at the old quarry near Richardson's Landing in Meade County, the top layers of the Fredonia, in immediate contact with the Talarocrinus bearing layers in the bottom of the Gasper, have an abundance of *Lithostrotion harmodites*, a fossil not known to range above the Fredonia, and, in other places, as at Webster quarry in the vicinity of Irvington, Breckinridge County, Ky., *Platycrinus huntsvillae* is abundant in coarse white oolite layers but a few feet below the bottom of the Gasper. As already described the contact of the Fredonia and Gasper is at some points in Breckinridge County also marked by a conglomerate and a bed of siliceous limestone containing an abundance of quartz grains.

The Bethel sandstone is known as far east as Fairview nearly on the line between Christian and Todd counties but was not observed at Elkton 10 miles farther east nor anywhere between Elkton and Breckinridge County. It is supposed that the Ohara limestone member of the Ste. Genevieve is present beneath the Bethel to its eastern limit, but how much farther east it may extend has not been determind. It is doubtful if it is in the section at Bowling Green, Warren County.

This identification of the formations from Breckinridge to Caldwell has been established beyond a reasonable doubt by fairly close tracing along their practically continuous outcrops between the two points, the

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formations, especially the Gasper and Fredonia oolites, preserving their distinctive lithologic and paleontologic characters by which they can be easily recognized. In the region between Caldwell County, Ky., and southeastern Illinois continuous tracing is impossible owing to the interruption and offsetting of outcrops by the many faults traversing that region. Nevertheless it is possible to identify the various Chester formations by their lithologic character and their fossils across this faulted region and determine with certainty the equivalent formational units in southeastern Illinois, the only formation undergoing such a change as not to be recognizable in southeastern Illinois by intrinsic characters being the Gasper oolite. As already described, between southeastern Crittenden County, Ky., and Illinois the Gasper oolite changes completely to shale or its upper part changes thus and its lower part laps out northwestward. As a result, the Gasper interval is occupied in southeastern Illinois by about 50 feet of soft shale described herein as the Ridenhower shale. While the Gasper cannot be traced in continuous outcrop and seems to change as described, yet the Bethel sandstone below it and the Cypress sandstone above can be in part followed continuously, or, where their outcrops are interrupted or offset by faults, can be satisfactorily identified by means of their relations to known fossiliferous formations such as the Ohara, Golconda, and Glen Dean, so that there is no doubt that they are the sandstone strata underlying and overlying the Ridenhower shale at Golconda, Ill., where all three (Bethel, Ridenhower and Cypress) are well exposed in the same section and whence they can be traced throughout Pope and Hardin counties, Illinois.

There seems to be no reasonable doubt, therefore, as to the correlation between west-central Kentucky and southeastern Illinois.

When it comes to the correlation betwen southeastern and southwestern Illinois, however, the case is different, as respects the correlation of the Ohara limestone member, the Bethel sandstone, the Gasper oolite, and perhaps the Cypress sandstone. Ulrich correlates the Bethel sandstone with the Aux Vases sandstone of the Mississippi Valley (See Plate 2, generalized sec-

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tions), while Weller regards the Aux Vases sandstone as absent in Ohio Valley. He thinks its horizon lies at the place of the conglomerate layer in the Ohara member 25 feet above the Rosiclare sandstone, as shown in section No. 3, Plate 3, and in the generalized section for Hardin County, Ill., and Crittenden County, Ky., Plate 2. The reasons for these correlations are somewhat too complicated to be given here. There are involved, however, further differences in correlation. Ulrich regards the upper Ohara as generally absent in Mississippi Valley, its place being just below the Aux Vases sandstone, and the Gasper oolite Ulrich correlates with the Renault, Paint Creek, and Ruma formations of Mississippi Valley. Weller, on the other hand, correlates the upper Ohara with the Renault. Owing to these differences of opinion and to the fact that the writer does not feel prepared at present to express an opinion of his own, the correlation of the units involved in the controversy is left undecided here. The correlation lines of Plate 2 express the correlations that are generally agreed upon. There is no question about the correlation of the formations above the Cypress sandstone except that Ulrich would correlate the Cypress with a considerable part of the Golconda formation. Nor is there probably any serious differences of opinion as to the correlation below the top of the Fredonia oolite member of the Ste. Genevieve limestone between Ohio and Mississippi Valley.

Ulrich presents a full statement of the question at issue in his paper in this volume and sets forth reasons for his views that apparently can be refuted only by disproving the correctness of his determination of fossil forms.

CYPRESS ("BIG CLIFTY") SANDSTONE.

The Cypress sandstone was named by Englemann* from Cypress Creek in southwestern Johnson and Union counties, Ill. It is the same as the Big Clifty sandstone of Norwood† and No. 1 of Ulrich's Birdsville section,‡ but the name Cypress has priority and should be re-

*Englemann, Henry, Geol. Survey of Illinois, Vol. 1, 1866.
†Norwood, C. J., Geol. Survey of Kentucky, N. Ser., Vol. 1, 1876.
‡Ulrich, E. O., U. S. Geol. Survey Prof. Paper 36, p. 61.

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tained. It is to be borne in mind that Ulrich erroneously correlated the Bethel sandstone with the Cypress and "Big Clifty." Cypress sandstone in the region treated in this report is a medium coarse-grained, medium hard, and generally rather thick-bedded to massively bedded sandstone, 40 to 85 feet thick and locally perhaps somewhat thicker. A sample of sand from a sand pit in a locally friable development of the sandstone at East View, Hardin County, Ill., is composed of clear quartz grains ranging from .1 to .5 millimeters in diameter, the majority of the grains being about .3 millimeter. The grains are sub-angular and bear evidence of considerable abrasion in transport.

The general appearance and average thickness of the Cypress is exhibited on Big Clifty Creek in Grayson County, Ky., where crossed by the Illinois Central Railroad. This is the type locality of Norwood's Big Clifty sandstone. Its appearance here is shown in the photograph, Plate 22-A.

A few miles northeast of Big Clifty Creek the Cypress has a rather more massive character as shown in the photograph, Plate 22-B.

At Sample and Stephensport in Breckinridge County, the Cypress is represented mainly by about 60 feet of shale with a sandstone layer in the middle 1 foot thick at Sample and 3 to 10 feet thick at Stephensport. The beginning of the change to shale is exhibited along the Fordsville branch of the Louisville, Henderson & St. Louis Railroad, 1 mile north of Garfield where the persistent and certainly recognizable *Productus inflatus* zone of limestone forming the top of the Gasper oolite is immediately overlain by 20 feet or so of shale, above which lies the upper 40 feet or so of the Cypress. Southward from this locality as at Garfield, on the head of Clover Creek southwest of Hardinsburg, at Big Clifty, and elsewhere, the *Productus inflatus* zone is immediately overlain by 60 feet of Cypress sandstone, while in the Sample section the *Productus inflatus* zone is overlain by the 60 feet of shale, as described above. These facts are brought out in sections Nos. 27, 28 and 30 of Plate 3. The sandstone is present and 50 feet thick on Ohio River near Richardson's landing 7 miles northwest of Brandenburg. Here it includes 20 feet of inter-

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PLATE 22A.

Photograph of the Cypress ("Big Clifty") sandstone on Big Clifty Creek one-fourth mile below the Illinois Central Railroad trestle. Looking east.

PLATE 22B.

Cypress ("Big Clifty") sandstone in a cut of the Illinois Central Railroad 1½ miles southwest of Stephensburg, Hardin County, Ky.

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bedded shale and sandstone in the space between 10 and 30 feet above the *Productus inflatus* zone, the upper 20 feet and lower 10 feet being thick bedded sandstone. The sandstone is well displayed on the valley walls in the vicinity of Garfield, Breckinridge County, which is built upon it and where it is 60 feet thick; on the head of Clover Creek southwest of Hardinsburg, where it is of massive character and 40 feet thick; at Mammoth Cave, where the hotel and town are built upon it; north of Bowling Green, Warren County, where it is 85 feet thick and forms the surface of a wide terrace sloping northward toward the edge of the coal field; along the road between Marion and Siloam school, Crittenden County, where the road follows a ridge capped with Cypress southwestward for over a mile beginning just west of the junction of the road to Bethel school; on the west bluff of Ohio River for one-half mile or so southwest of the mouth of Big Grand Pierre Creek; and on the bluff immediately south of Golconda, where the northward-dipping sandstone of the cliff is Cypress. The town is built upon this sandstone.

The Cypress sandstone caps and is the primary condition of the formation of the conspicuous terrace visible to the north and west of the Louisville & Nashville Railroad for so much of the distance between Munfordville and Bowling Green. This terrace is also a conspicuous feature north of Elkton and Fairview. A photograph taken about 1 mile north of Fairview exhibits the terrace with the bluff below on which outcrops the Gasper oolite, which extends down to the Ste. Genevieve limestone outcropping on the plain below.

No fossils have been found in the Cypress sandstone except locally, as near Scottsburg, Caldwell County, in the thin basal layers where *Archimedes confertus*, Ulrich, occurs. In the probably equivalent Hartselle ("La Grange") sandstone member of the Bangor limestone in Colbert County, Ala., there are many large trunks and stumps of the great Carboniferous scale tree *Lepidodendron*. Remains of such trees exist in the Cypress sandstone in Kentucky.

The Cypress sandstone is not especially important from an economic standpoint. At East View, Hardin

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County, it yields sand from an unconsolidated portion, and the asphalt rock about 1 mile south of Garfield, at one time exploited, is supposed to be in the Cypress sandstone.

The correlation of the Cypress throughout Illinois and Kentucky is sufficiently indicated in the preceding description. There are good reasons for correlating it also with the sandstone lentil in the Newman limestone of northern Tennessee (See Standingstone and Wartburg folios of the United States Geological Survey), and with the Hartselle sandstone of Alabama, which is the same as the Oxmoor sandstone of Hayes in the Stephenson and Gadsden folios. The Hartselle sandstone is supposed to extend the entire length of Sequatchie or Browns Valley from Blount Springs, Ala., to its northern end about 20 miles northeast of Pikeville, Tenn. This sandstone is probably the same as that outcropping on the west escarpment of Cumberland Plateau a short distance west of Rockhouse Station between Bon Air and Sparta, Tenn. In this section immediately beneath the sandstone, *Productus inflatus* is present as in Breckinridge County, Ky., and immediately following the *Productus inflatus* zone below and extending down to the Ste. Genevieve limestone with *Platycrinus huntsvillae,* is about 80 feet of oolitic limestone that is undoubtedly the Gasper oolite. This sequence proves almost beyond question that the sandstone in the section east of Sparta is Cypress. The position of the Cypress being the same as that of the Hartselle in the head of Sequatchie Valley whence the Hartselle can be traced southward into its type locality, there seems no good reason to doubt the equivalency of the Cypress and the Hartselle. The importance of this identification, if correct, is that it furnishes a datum plane from which the formations of Chester age in the Appalachian Valley can be compared with those of Ohio and Mississippi valleys.

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GOLCONDA FORMATION.

The Golconda formation is named from Golconda, Ill., just north of which the full thickness of the formation outcrops on the river bluff. The name was first used by Ulrich in a paper read before the Geological Survey of America in December, 1915. The Golconda includes that part of the Chester section between the Cypress sandstone below and the Hardinsburg sandstone, next to be described, above. At Golconda there is, directly above the Cypress, about 20 feet of dark shale, above which is 10 feet or so of dark, argillaceous, coarsely crystalline or fragmental fossiliferous limestone called the *Pterotocrinus capitalis* zone from the presence of abundant dismembered parts of that unique and characteristic crinoid. *Pentremites obesus,* one of the largest of the Pentremites, also occurs in this zone. The *Pterotocrinus capitalis* zone is overlain by 80 feet of shale and limestone, the shale so far as the incomplete exposure permits one to judge, largely predominating and the limestone occurring as layers scattered through the shale. These limestone layers are argillaceous and ferruginous weathering to a lemon yellow color. A thin layer of red shale was observed. Above this shale and limestone segment of the Golconda is about 30 to 40 feet of solid limestone apparently fairly pure calcium carbonate. Directly in contact with this limestone above is the overlying Hardinsburg sandstone forming a cliff 40 feet high and extending along the brow of the bluff for several miles above Golconda.

This limestone forming the upper part of the Golconda formation is to be utilized by the new cement mill now being established at Golconda.

The Golconda formation is persistent throughout Pope and Hardin counties, Ill., and can be recognized by its position between the Cypress and Hardinsburg sandstones, both of which can be identified by independent criteria, in the section northwest of Bowling Green and in various sections in Breckinridge County. In the section along the road to Richardsville northwest of Bowling Green the lower part of the Golconda is apparently pure gray limestone and contains beds of pure oolite. (See Section 11, Plate 3.) On the road towards Browns-

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ville on the contrary, several miles northeast of the last mentioned locality, the formation has 60 feet of shale above and 30 feet, mostly limestone, below. The shale includes a 5-foot bed of shaly sandstone near the bottom.

On the headwaters of Clover Creek southwest of Hardinsburg the Golconda is composed of red and green shale below, 40 feet thick, and limestone above, 30 feet thick. At Hardinsburg it is 50 feet thick, limestone above and shale below. In the section at Stephensport it is reduced to the top 30 feet of limestone. (See Sec. 27, Plate 3).

With the exception of the *Pterotocrinus capitalis* zone near the bottom, the Golconda is rather sparsely fossiliferous. *Pterotocrinus capitalis* is not known east of Crittenden County, Ky. It is reported as far west as eastern Johnson County, Ill. Possibly these are about its east-west limits. Since the Golconda is only about half as thick in Breckinridge County, Ky., as at Golconda, Ill., and its eastern representative seems to be the higher portions, it is reasonably inferred that deposition began in a basin at first restricted to Ohio Valley in western Kentucky and southern Illinois and later spread outward. It would follow that the lower beds with the characteristic *Pterotocrinus capitalis* and *Pentremites obesus* were deposited only in the Ohio Valley and that by the time that the wider transgression of the Golconda sea had been consummated those highly specialized forms had become extinct; hence their rather restricted known geologic and geographic limits. In the *Pterotocrinus capitalis* zone and in the upper limestone in Breckinridge County, Archimedes and Pentremites are quite plentiful. The following list shows the fauna of the Golconda formation as represented in some collections made near Golconda, Ill., and also in Crittenden County, Ky.

LISTS OF FOSSILS FROM THE GOLCONDA FORMATION.

Triplophyllum spinulosum. Edwards and Haime.
Pterotocrinus capitalis. Lyon.
Pterotocrinus depressus var. Lyon and Casseday.
Pentremites obesus. Lyon.
Pentremites godoni. Defrance.
Pentremites pyriformis. Say.

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Fistulipora sp.
Stenopora sp.
Anisotrypa? sp.
Fenestella sp.
Archimedes communis. Ulrich.
Archimedes meekanus. Hall.
Archimedes swallowanus. Hall.
Archimedes lativolvis. Ulrich.
Archimedes terebriformis? Ulrich.
Archimedes confertus. Ulrich.
Septopora subquadrans. Ulrich.
Lyropora quincunxialis? Hall.
Rhombopora sp.
Crania chesterensis. Miller and Gurley.
Productus arkansanus?
Productus ovatus. Hall.
Diaphragmus elegans. (Norwood and Pratten.)
Pustula (Echinoconchus) genevievensis. Weller.
Camarophoria explanata. (McChesney.)
Spirifer leidyi. Norwood and Pratten.
Spirifer pellaensis? Weller.
Spiriferina spinosa. Norwood and Pratten.
Spiriferina transversa. (McChesney.)
Composita trinuclea? (Hall.)
Cliothyridina sublamellosa. (Hall.)

Of these forms *Pterotocrinus capitalis* and *Pentremites obesus* are not known to occur outside of the Golconda, and *Archimedes lativolvis* is identified doubtfully only in the Gasper. These peculiar forms with others are illustrated in Plate 23.

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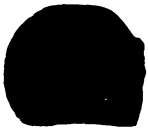

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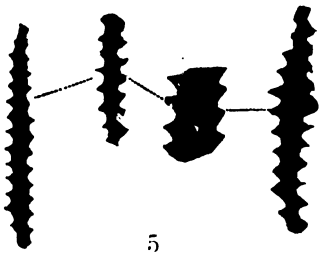

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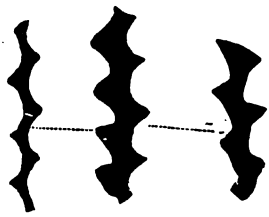

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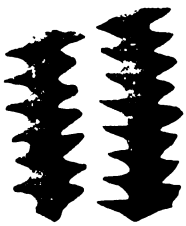

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PLATE 23.

Fossils from the Golconda and other formations.

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FOSSILS OF THE GOLCONDA AND OTHER FORMATIONS.

Plate 23.

1-4 Pterotocrinus capitalis. Lyon. No. 2, a complete head showing the position of the massive summit plates at the top margin. 1-3, detached summit plates. These are the parts most commonly found. 4, the two basal plates viewed from the under side showing the place of attachment to the stem in the center. This part is commonly found also. Restricted to the basal part of the Golconda in a small area in western Kentucky and southeastern Illinois. Nos. 1, 3, and 4, after Ulrich; 2 after Wachsmuth and Springer.

5 Archimedes compactus. Ulrich. Left hand specimen wound to left, others wound to right. Common form in the Golconda, Gasper, and Glen Dean. After Ulrich.

6 Archimedes terebriformis. Ulrich. Left hand specimen wound to left. Common in the Golconda and Glen Dean. Doubtfully identified by Ulrich from the Gasper. After Ulrich.

7-9 Pentremites obesus. Lyon. Lower part of the Golconda formation associated with Pterotocrinus capitalis and having about the same stratigraphic and geographic range. Natural size. One of the largest species of Pentremites. After Ulrich.

10 Archimedes lativolvis. Ulrich. Golconda formation. A similar form in the Gasper. After Ulrich.

11 Archimedes swallowanus. Hall. One specimen wound to right and the other to left. Golconda formation. A similar form in Glen Dean and Menard. After Ulrich.

12-14 Spiriferina spinosa. (Norwood and Pratten.) After Weller. Distinguished from Spirifer by its spinose and puctate shell. One of the most common shells throughout the Chester.

15-17 Spiriferina transversa. (McChesney.) After Weller. Marked like Sp. spinosa but finer markings. One of commonest Chester fossils.

The eastward correlation of the Golconda has been set forth. Its representative in the Mississippi Valley is probably to be found in the lower part of the Okaw formation. (See generalized columnar section sheet.) Ulrich, however, gives reasons for believing that the Golconda is absent in the Mississippi Valley in Illinois. (See his paper this volume.) Southward in Tennessee and Alabama it should be represented by the lower part of the limestone mass above the Hartselle sandstone or above the "Newman" sandstone lentil in the Newman limestone, as in the Standingstone quadrangle, Tenn.

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HARDINSBURG SANDSTONE.

Hardinsburg is here introduced for the third persistent sandstone stratum from the bottom of the Chester group or the fourth if the Fredonia oolite with the Rosiclare sandstone are included in that group. The name is from Hardinsburg, Breckinridge County, Ky., which is located upon the sandstone. At Hardinsburg a thickness of about 30 feet is exposed. As the sandstone is the highest rock exposed and extends upward to the cover of soil, it is not known how much thicker it may have been originally. It is composed of shaly sandstone above, a coarse-grained massive bed about 10 feet thick in the middle, and 10 feet of somewhat thinner bedded rock below, resting upon limestone in the top of the Golconda formation. This fine exposure is in the northern environs of the town. The usual condition of the sandstone is thin-bedded and flaggy, rather fine-grained and hard, and somewhat argillaceous and ferruginous. At Sample and Stephensport (Sections 27 and 28, Plate 3), southeast of Cloverport (Section 23, Plate 3), and on the Illinois Central Railroad just east of Big Clifty Creek, the sandstone is flaggy and 20 feet or more in thickness. It is about 35 feet thick in the section along the road up the hill immediately south of Stephensport where both its top and bottom can be determined. In the section on the Greencastle road, northwest of Bowling Green, it is 40 feet thick and partly rather thick-bedded and coarse-grained. In Crittenden County southwest of Marion, this sandstone forms the ridge to the northwest of Claylick Creek in the bottom of which its top is exposed just below the point where the road, going southwestward turns down the creek. In Hardin County, Ill., it exhibits both flaggy and thick bedded phases. At one point it is very evenly bedded and is quarried on a small scale for flagstones. In the bluff north of Golconda and westward toward Brownfield, it is a coarse thick-bedded sandstone 40 feet thick yielding large blocks to the slopes below.

The Hardinsburg sandstone can be certainly identified by the overlying Glen Dean limestone with its profuse and characteristic fauna. This limestone, next to be described, is everywhere present in the region under description.

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GLEN DEAN LIMESTONE.

The Glen Dean limestone is named from Glen Dean in the southern part of Breckinridge County, Ky. This name is adopted because of the excellent exposure of the limestone along the railroad on both sides of Glen Dean.

The Glen Dean is composed of varying proportions of limestone and shale and includes locally, at least, a little sandstone. The bottom segment of the formation at several widely separated points in Breckinridge County is about 10 feet of green and red shale lying upon the flaggy Hardinsburg sandstone. In places this shale is absent as on Caney Creek 5 miles southeast of Cloverport (See Section 23, Plate 3), where the Hardinsburg sandstone is followed by limestone without intervening shale. In all sections either overlying the shale or the Hardinsburg sandstone where the shale is absent, is 30 to 60 feet of limestone, thick-bedded, or thin-bedded, in part generally rather coarse-grained or crinoidal, and light to bluish gray in color. Above this persistent limestone segment is a varying thickness of limestone and shale—say 40 to 100 feet in different sections in Breckinridge County. A little red shale occurs in this shale segment as in the section on Caney Creek already referred to. On the Greencastle road northwest of Bowling Green (See Section 11, Plate 3) the Glen Dean consists so far as exposed, and it seems to be about all exposed, of about 40 feet of bluish-gray, medium thick-bedded, limestone with the characteristic fossils *Prismopora sendata* and *Archimedes laxus*. On Claylick Creek southwest of Marion, Crittenden County, the bottom beds of the Glen Dean, which only are exposed there, are rather argillaceous and sandy. The basal layers are crowded with Agassizocrinus bases and a slender Archimedes. In Hardin and Pope counties, Ill., the Glen Dean is also composed of shale with thick limestone layers carrying the characteristic fossils of the formation. In Mississippi Valley the Glen Dean can be surely identified by its fossils. Here it is represented by shaly limestone constituting the upper part of the Okaw formation.

The thickness of the Glen Dean varies from 40 to 50 feet, as northwest of Bowling Green and in Pope and

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Hardin counties, Ill., to 180 feet, as on Caney Creek 5 miles southeast of Cloverport, Breckinridge County, Ky. Its thickness and general make up are well exhibited in Sections 11, 19 and 23, Plate 3.

The best display of the Glen Dean known to the writer is that already referred to on Caney Creek southeast of Cloverport, where it also reaches the maximum observed thickness of 180 feet. It is also well displayed, especially the lower 30 feet of limestone, at Glen Dean, Breckinridge County, on the Fordsville branch of the Louisville, Henderson & St. Louis Railroad. The lower limestone is exposed in the railroad cuts for a mile or so on each side of the town and the upper shaly beds on the highway west of town. There is a good exhibition of the formation at a quarry near the Greencastle road about 2 miles southwest of Richardsville, Warren County, Ky. A good exposure of the highly fossiliferous beds occurs in the town of Carrsville, Livingston County. Although persistent, it is very poorly exposed in Pope and Hardin counties, Ill. It is there apparently largely soft shale inclosing some thick limestone layers.

The Glen Dean is highly fossiliferous as shown by the following list which is based largely upon collections from Breckinridge County:

LIST OF FOSSILS FROM THE GLEN DEAN LIMESTONE.

Triplophyllum spinulosum. (Edwards and Haime.)
Meniscophyllum? sp.
Pterotocrinus depressus. Lyon and Casseday.
Pterotocrinus acutus. Wetherby.
Pterotocrinus acutus var. bifurcatus. Wetherby.
Dichocrinus sp.
Eupachycrinus sp.
Agassizocrinus conicus. Owen and Shumard.
Pentremites spicatus. Ulrich n. sp.
Pentremites pyramidatus. Ulrich.
Pentremites pyriformis. Say.
Pentremites godoni. Defrance.
Pentremites sp.
Stomatopora? sp.
Fistulipora sp.
Meekopora clausa. Ulrich.
Cheilotrypa hispida.
Stenopora ramosa. Ulrich.

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Stenopora sp.
Anisotrypa solida. Ulrich.
Fenestella sp.
Polypora sp.
Ptilopora sp.
Septopora cestriensis. Prout.
Septopora subquadrans. Ulrich.
Lyropora ranosculum. Ulrich
Archimedes meekanus. Hall.
Archimedes swallowanus. Hall.
Archimedes laxus. Hall.
Archimedes sublaxus. Ulrich.
Prismopora serrulata. Ulrich.
Streblotrypa nicklesi. Ulrich.
Orthotetes kaskaskiensis. (McChesney.)
Productus ovatus. Hall.
Productus inflatus? McChesney.
Diaphragmus elegans. (Norwood and Pratten.)
Camarophoria explanata. (McChesney.)
Dielasma illinoisense. Weller.
Girtyella indianensis. (Girty.)
Spirifer increbescens. Hall.
Spirifer leidyi. Norwood and Pratten.
Martinia sulcata. Weller.
Reticularia setigera. (Hall.)
Spiriferina spinosa (Norwood and Pratten.)
Spiriferina transversa. (McChesney.)
Composita trinuclea. (Hall.)
Composita subquadrata. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria vera. (Hall.)
Eumetria costata. (Hall.)
Myalina angulata? Meek and Worthen.
Conocardium sp.
Bellerophon sublevis. Hall.
Platyceras chesterense. Meek and Worthen.
Griffithides.

FOSSILS OF THE GLEN DEAN LIMESTONE AND OTHER FORMATIONS.

Plate 24.

1 Pentremites pyramidatus. Ulrich. Glen Dean limestone on Caney Creek about 5 miles southeast of Cloverport, Breckinridge County. Probably restricted to the Glen Dean.
2 Pentremites pyramidatus? Same locality and formation as figure 1.

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3-4 Pentremites spicatus. Ulrich. n. sp. So named from the projecting tips of the interambulacral plates some of which are restored in figures 3 and 4. Glen Dean limestone 1 mile east of Cloverport, Ky. Doubtfully identified by Ulrich in the Golconda formation. Common to abundant in the Glen Dean throughout western Kentucky and in southeastern Illinois. May be regarded as one of the best index fossils of the Glen Dean.

5 Pentremites tulipaeformis. Hambach. Glen Dean limestone only. Specimen from Caney Creek 5 miles southeast of Cloverport.

6 Pentremites brevis. Ulrich. n. sp. Glen Dean limestone only.

7 Pentremites canalis. Ulrich. n. sp. Distinguished by the distinct narrow canal-like furrow at the bottom of the abulacral area. Glen Dean limestone only.

8-10 Prismopora serrulata. Ulrich. Glen Dean limestone. Railroad cut 2 miles northeast of Cloverport, Ky. 8, direct view of one face two times enlarged; 9, perspective view of fragment natural size; 10, end view of specimen 8, showing triangular cross section, natural size. The triangular form and serrate edges of this form render its identification certain, and this in connection with its almost invariable presence in every outcrop of the Glen Dean from central Kentucky to western Illinois makes it an invaluable guide fossil to that formation. It occurs at other horizons, but very rarely.

11 Lyropora ranosculum. Ulrich. After Ulrich. Glen Dean limestone to which it seems to be restricted. The form consisted of a solid U-shaped frame work between the arms of which was stretched a network similar to that in Fennestella. The solid framework is about all that is usually preserved. There are 4 other species, some of which occur in the Ohara member of the Ste. Genevieve. They all occur in the Glen Dean.

12 Pterotocrinus depressus. Lyon and Casseday. A thin, flat, wing plate, homologous with that of P. capitalis shown on Plate 23. Glen Dean and higher Chester formations. A similar form occurs in the Gasper and Golconda. Specimen figured from the Glen Dean at Sloans Valley. Ky. After Ulrich.

13 Archimedes meekanus. Hall. Fredonia oolite to Clore formation. Specimens like the small one on the left common in the Glen Dean. After Ulrich.

14 Pterotocrinus bifurcatus. Wetherby. Basal view. After Wachsmuth and Springer. The forked wing plates especially distinguish this species. These are usually found separate and are entirely characteristic of the Glen Dean as the species is known from no other horizon.

15-16 Pterotocrinus acutus. Wetherby. Side views of one of the wing plates. From the Glen Dean at Sloans Valley, Ky. Characteristic Glen Dean fossil. After Ulrich.

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17 Archimedes laxus. Hall. Common in the Glen Dean throughout its geographic range and at many places associated with Prismopora serrulata. Rarely occurs outside of the Glen Dean. This and Prismopora serrulata occurring together may be regarded as almost certain evidence of the Glen Dean.

18-19 Dielasma illinoisensis. Weller. Ohara to Glen Dean. After Weller.

21 Pentremites fohsi. Ulrich. Glen Dean near Marion, Ky. This form while resembling P. obesus of the Golconda (Plate 23) can be distinguished by its generally smaller size and depressed ambulacral areas. In P. obesus these are flatter and the opposite halves are arched. Characteristic of the Glen Dean. After Ulrich.

22-24 Eumetria costata. (Hall.) Specimens from the Chester group, Chester, Ill. Found by Girty in the writer's collection in Breckinridge County, Ky., only in those from the Glen Dean. After Weller.

Of the fauna above listed the following are either restricted to the Glen Dean or occur so rarely at other horizons as to diminish very slightly their correlational value. *Archimedes laxa, Prismopora serrulata, Pentremites spicatus, Pterotocrinus bifurcatus, Pterotocrinus depressus* and *Pterotocrinus acutus.* This association, of which two or more species are almost invariably present in every exposure of the Glen Dean from Pulaski County, Ky., to Mississippi River in Randolph County, Ill., serves to identify the formation beyond a doubt as the same between those extremes of locality and establishes a sure datum plane for the comparison of sections and the sequence of formation above and below it. By this means the different stratigraphic units of the Chester group can be certainly identified or correlated throughout western Kentucky and southern Illinois.

These characteristic forms and others are illustrated on Plate 24.

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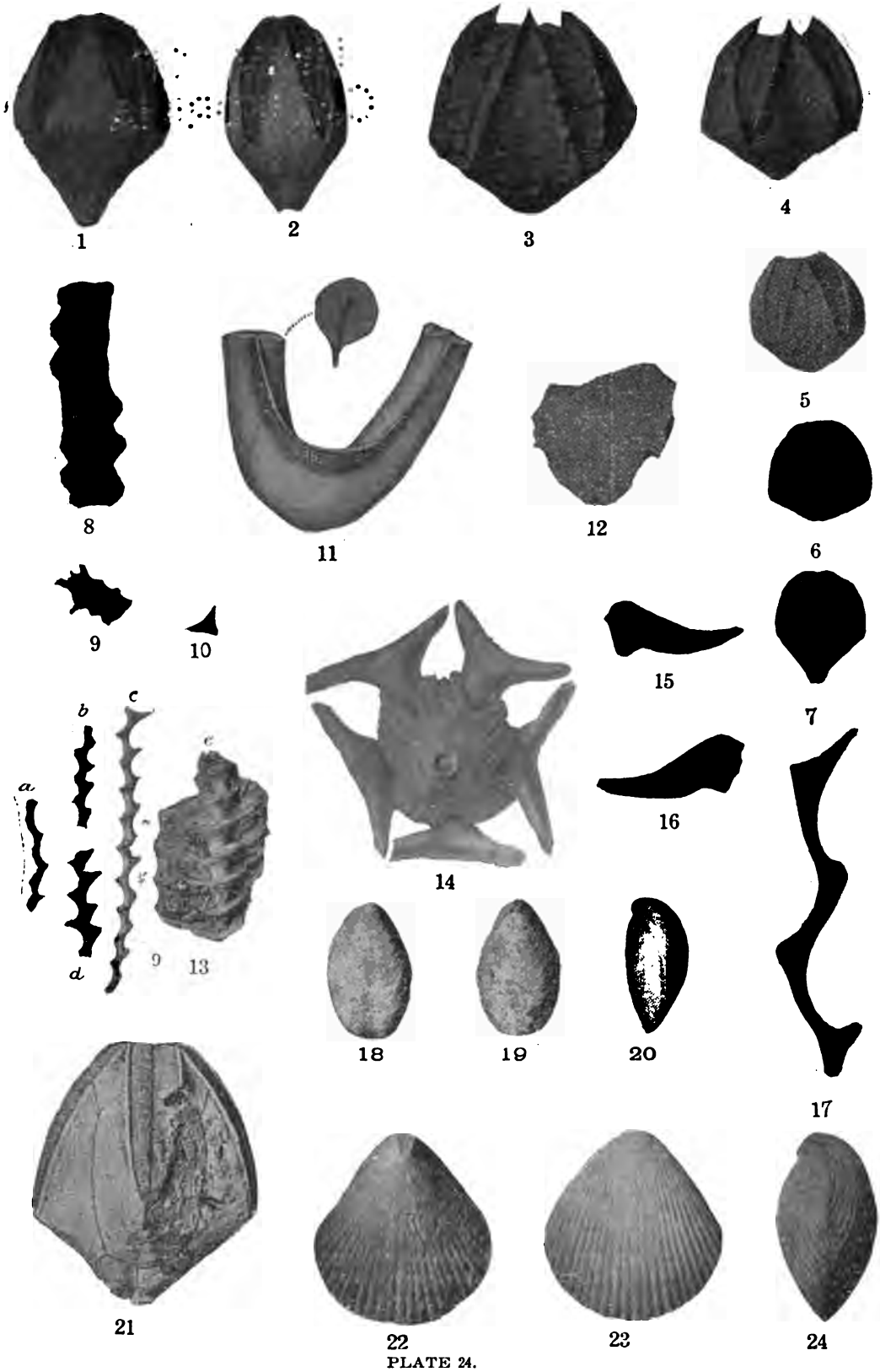

PLATE 24.

Fossils from the Glen Dean limestone and other formations.

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TAR SPRINGS SANDSTONE.

The Tar Springs sandstone was named by Owen from the Tar Springs 3 miles south of Cloverport, Breckinridge County. These springs issue from the sandstone and yield a little petroleum, whence the name. Tar springs from the sandstone occur at a few other points, one of which is at the foot of the river bluff about 2 miles west of Cloverport.

The sandstone varies in general character from place to place. At Tar Springs, the type locality, in the vicinity of Cloverport and on Rock Lick Creek as far south as Glen Dean, it is a thick-bedded to massive, medium coarse-grained and medium firmly cemented quartz sandstone. Locally it is highly cross bedded. (See photo, Plate 25-B.) In a specimen collected 1 mile southwest of Cloverport the grains range from .1 to .5 millimeter in diameter, those of the larger diameter being very few. It is estimated that 90 per cent. of the grains are about .3 millimeter in diameter and fairly well rounded or at least sub-angular. The ordinary aspect of the sandstone is shown in the photographs. (Plates 25-A and 25-B.)

Where massively developed, as in the localities cited, the Tar Springs is about 50 feet thick. Five miles southeast of Cloverport as on the ridge between Caney Creek and Beech Fork, the Tar Springs sandstone has changed to a thin bedded and shaly character. At Leitchfield in Grayson County it may be represented by about 5 feet of shaly sandstone next above the Glen Dean limestone. West of Cloverport on the river bluff, the Tar Springs maintains its heavy bedded character to a point about 1½ miles east of Skillman and then in the distance of one-half mile degenerates to a shaly condition in which there is no resemblance to its facies about Cloverport. Along the bluff beginning about 1 mile west of Cloverport, the sandstone makes a cliff 50 feet high which is a conspicuous feature from Cloverport in the early morning when illuminated by the direct rays of the sun. In Warren County the Tar Springs is a rather thick-bedded sandstone at least 30 feet thick, as shown on the Bowling Green-Woodbury road 2 to 4 miles southeast of Riverside. The sandstone is present and of good thick-

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PLATE 25A.

Tar Springs sandstone 1 mile southwest of Cloverport, Breckinridge County, Ky. Looking east.

PLATE 25B.

Tar Springs sandstone 5 miles southwest of Cloverport. Looking north.

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ness in Crittenden County, Ky., and in Hardin County, Ill., it seems to reach its maximum development. Here it appears to be 150 feet thick, its middle part being shale and shaly micaceous sandstone, the surfaces of the layers being blackened by a thin film of carbonaceous matter. A coal bed occurs in this part and was seen at one point in Hardin County, Ill. The upper and lower thirds are rather coarse and thick-bedded. The Tar Springs is known as far west as Moscow school, in Johnson County, Ill., where it as elsewhere, overlies the Glen Dean limestone with its characteristic fauna. It may be represented in the bluff at Chester, Ill., by a lens of sandstone which is there present between the Okaw and Menard limestones.

The Tar Springs is somewhat notable for the relative abundance of plant remains. Fern pinnules belonging to the genus *Cardiopteris* have been found in the shaly facies 1 mile east of Skillman, the next station west of Cloverport on the Louisville, Henderson & St. Louis Railroad, and in the shaly facies in Hardin County, Ill. These are referred to *C. polymorpha* by White, who says the species is probably identical with that occurring in the Chester at Abbs Valley, Va. Stigmaria, sigillaria and lepidodendron, and in some cases trunks of considerable size, were observed. The Stigmaria is compared with *S. verrucosa*. One species of Lepidodendron is of the type of *L. velthemianum* of the carboniferous limestone of Europe and the other is doubtfully identified as *L. acuminatum*. The form referred to *L. velthemianum* is said by White to be apparently identical with a form occurring in the Stanley shale near Tuskahoma Okla.

As the name implies the sandstone is asphaltic though in reality only locally so. About 2 miles west of Cloverport in a railroad cut the basal 5 feet or so is highly charged with bitumen and presumably the petroliferous springs at Tar Springs, the type locality, have their source in an asphaltic portion of the sandstone. So far as has come under the writer's observation the quantity of asphaltic rock and the conditions under which such as is known would have to be exploited do not justify any expectation that the asphaltic deposits are commercially important.

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MENARD LIMESTONE.

The Menard limestone (No. 6 of Ulrich's Birdsville section, P. P. 36, p. 61) was so named by Weller* from Menard, Ill., near Chester, Randolph County. The Menard is predominantly composed of rather thick-bedded limestone weathering smooth and blue. It contains a subordinate amount of shale in places; in others limestone seems to make up the entire thickness. More commonly, however, there is a considerable thickness of shale in the top part just under the Palestine sandstone next to be described. The shale is soft, dark, and of purely clay composition. The most characteristic feature of the Menard is the fairly thick-bedded, fine-grained to nearly non-granular, dove colored or light gray limestone, weathering with a smooth, light bluish-gray sur-

PLATE 26.

Menard limestone on Gravel Creek, about 3½ miles northwest of Chester, Ill.

*Weller, Stuart, Mon. Mississippian Brachiopoda: Illinois Geol. Survey, p. 28, 1914.

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face. The limestone layers are in places at least, rather uneven surfaced as shown in Plate 26. These aspects of the formation are those most commonly exhibited in exposures. The limestone of this character, which seems to make up the larger part of the formation, has the appearance of a good degree of purity and should be suitable for industrial uses. The formation contains also some ferruginous and argillaceous, coarse-grained, dark limestone weathering yellow, and some thin argillaceous limestone layers in the shale. But very little chert occurs in the Menard anywhere. Its general appearance is shown in the photograph, Plate 26.

According to the best determinations that can be made, the Menard is quite uniformly 80 to 100 feet thick in Crittenden County, Ky., and Hardin County, Ill., but is reported by Ulrich not to exceed 50 feet at Claxton, Caldwell County. This southeastward thinning is in harmony with its total disappearance farther east as described in subsequent pages. It is somewhat more than 100 feet at Tribune in Crittenden County, Ky.

Some of the best exposures of the Menard are at the locality on Gravel Creek, 2½ miles northwest of Chester, Randolph County, Ill., at which the photograph, Plate 26, was taken, and at Tribune, Crittenden County, Ky. As already mentioned in the description of the Gasper oolite, the limestone at Tribune was supposed by Ulrich* to be the same as the Gasper oolite in western Christian County, to which he therefore applied the name Tribune. In reality the limestone at Tribune, the Menard, is No. 6 of Ulrich Birdsville section in Professional Paper No. 36. Exposures of the Menard are common and it apparently occupies a large part of the area mapped by Ulrich† as Birdsville in the vicinity of Farmersville and Ruth in Caldwell County. It was recognized in its typical character by Ulrich as far east as Claxton, Caldwell County, but its eastward extent beyond that region is unknown. It is known to be absent from the section northwest of Bowling Green. Here the Tar Springs sandstone is overlain by 200 feet or possibly

*Ulrich, E. O., The lead, zinc, and fluorspar deposits of western Kentucky: U. S. Geol. Survey Prof. Paper 36.

†Op. Cit.

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more of beds composed mainly of shale, but which include some limestone. This mass is described a little farther on as the Buffalo Wallow formation. In Breckinridge County a pure bluish-gray crystalline limestone 1 to 15 feet thick on top of the Tar Springs sandstone is probably Menard. The greatest thickness seen is in the valley just east of the old Victoria cannel coal mine 10 miles south of Cloverport, Breckinridge County. At this point the limestone is about 15 feet thick, of Menard type, and contains the fossil *Sulcatopinna missouriensis* one of the reliable guide fossils of the Menard.

The Menard is a highly fossiliferous formation. A list of its species, based on collections from Pope and Hardin counties, Ill., is given below. The list is not a complete one of the Menard fauna.

PARTIAL LIST OF FOSSILS FROM THE MENARD LIMESTONE.

Triplophyllum spinulosum. Edwards and Haime.
Pentremites specabus? Ulrich. n. sp.
Pentremites sp.
Eupachycrinus? sp.
Pterotocrinus depressus. Lyon and Casseday.
Fistulipora sp.
Stenopora sp.
Anisotrypa sp.
Leioclena sp.
Fenestella sev. sp.
Archimedes meekanus. Hall.
Archimedes swallowanus. Hall.
Rhombopora sp.
Orthotetes kaskaskiensis. McChesney.
Diaphragmus elegans. (Norwood and Pratten.)
Pustula echinoconchus alternata. (Norwood and Pratten.)
Camarophoria explanata. (McChesney.)
Spirifer leidyi. Norwood and Pratten.
Spirifer increbescens. Hall.
Spiriferina spinosa. (Norwood and Pratten.)
Spiriferina transversa. McChesney.
Composita subquadrata. (Hall.)
Composita trinuclea? (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria vera. (Hall.)
Sulcatopinna missouriensis. (Swallow.)

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Of the fossils listed above, the large form of *Spirifer increbescens* and of *Composita subquadrata* seem to appear in the Menard. Sulcatopinna is more common in the Menard than in any other formation and may be considered its most characteristic form. The first two mentioned are even more common and abundant in the Clore formation to be described and in the upper part of the Buffalo Wallow formation, which doubtless corresponds to Clore. The Sulcatopinna occurs also in the Clore but is very scarce in that formation. In the Menard its presence is quite commonly to be detected on the weathered surfaces of the layers by the cross section of its valves. It is usually accompanied by numbers of specimens of large Bellerophon. For illustrations of these fossils see Plate 28.

PALESTINE SANDSTONE.

The Menard limestone is succeeded above by the Palestine sandstone, so named by Weller* from Palestine township of Randolph County, Ill., near Chester, where the sandstone outcrops extensively. The Palestine is generally a medium-grained, flaggy, somewhat ferruginous sandstone and therefore weathers to a buff color. It seems to have a quite uniform thickness of about 75 feet. It is persistent throughout southern Illinois, being present and equally well developed in Randolph and Hardin counties on opposite sides of the State. It extends into Crittenden County, Ky., but seems to diminish eastward from southern Illinois, for in the vicinity of Tribune, Crittenden County, it is apparently thinner than in Hardin County, Ill., and largely of laminated and shaly character. Its southeastern extension in eastern Caldwell and northern Christian, Todd, and Logan counties is unknown. It is absent in Warren County and northward though possibly represented by a few thin, greenish, argillaceous layers in the Buffalo Wallow formation of Breckinridge County.

The sandstone is unfossiliferous except for an occasional specimen of Lepidodendron or Stigmaria. A form compared by White with *Lepidodendron modulatum* was collected from the Palestine in the vicinity of Vienna, Johnson County, Ill.

*Weller, Stuart, Mon. 1, Illinois Geol. Survey, 1914, p. 29.

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CLORE FORMATION.

The Clore is the top formation of the Chester group and of the Mississippian series of the Mississippi Valley. The name was applied by Weller* from Clore school in Randolph County, Ill.

Lithologically, the Clore is composite, being made up of shale, limestone and sandstone, the proportions being in the order named, at least in Pope and Hardin counties, Ill., and Crittenden County, Ky. The shale is of the soft clay composition of the Chester shales in general. It weathers down to excessively thin, small flakes or to clay. It is mostly bluish when fresh but weathers to a greenish color. There is a little red shale. The limestone of the Clore varies considerably in character at different horizons and localities. It occurs as beds or layers up to 20 or 30 feet thick separated by greater thicknesses of shale. Apparently beds over 10 feet thick are exceptional. A good deal of it resembles Menard limestone, being thick-bedded, fine-grained to compact and dense, and bluish-gray in color. Thin or shaly layered, coarse-grained, highly fossiliferous limestone is common. Much of the limestone is in layers a foot or more thick that are rather ferruginous and weather to a yellow color. This feature is more prevalent in the Clore than in any of the other Chester limestones and is a good indicator for its identification, but such layers do occur to a small extent in the Menard limestone, and can not be taken as a sure criterion of the Clore. Some layers of sandy limestone occur which in weathering have the appearance of a dark, ferruginous, friable sandstone. When broken open, however, the interior unleached parts of such layers plainly reveal their essentially calcareous character. In the specimens examined the interior has all the appearance of a blue limestone surrounded by a crust of brown sandstone one-half inch thick or so. In most of its area chert is absent from the Clore but in the northern part of Pope County, Ill., there is an abundance of small gray or yellowish chert fragments scattered upon the surface that are derived from limestone layers in the Clore.

The sandstone in the Clore makes a very small part

*Op. Cit., p. 29.

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of the mass, being limited to an occasional layer a few inches or few feet thick. It is doubtful whether a thickness of 10 feet is ever reached except possibly by a thinly laminated stratum with irregular bedding and bedding planes stained by a film of carbonaceous matter that occurs in the vicinity of Herod, Pope County, Ill. The sandstone is almost all fine-grained and of greenish color. A little white, siliceous, rather coarse-grained but laminated sandstone has been observed. Owing to conditions of outcrop and exposure an accurate determination of the thickness of the Clore can hardly be made. The best data obtainable in Hardin County, Ill., and Crittenden County, Ky., point to a thickness of about 150 feet. Many of the limestone layers and some of the calcareous sandstone layers in the Clore are highly fossiliferous. From them the fossils of the following list have been obtained, chiefly in Hardin County, Ill. This is not a complete list of the Clore fauna. For a larger list, the material being from western Kentucky, see Ulrich's paper, this volume.

PARTIAL LIST OF FOSSILS FROM THE CLORE FORMATION.

Triplophyllum spinulosum. Edwards and Haime.
Pentremites serrata. Ulrich. n. sp.
Pentremites aff. godoni. Defrance.
Agassizocrinus conicus. Owen and Shumard.
Pterotocrinus depressus. Lyon and Casseday.
Anisotrypa sp.
Fenestella sev. sp.
Polypora sp.
Archimedes meekanus. Hall.
Septopora subquadrans. Ulrich.
Prismopora serrulata. Ulrich.
Rhombopora sp.
Coeloconus granulosus. Ulrich.
Productus ovatus. Hall.
Diaphragmus elegans. (Norwood and Pratten.)
Camarophoria explanata. (McChesney.)
Dielasma sp.
Spirifer increbescens. Hall.
Spiriferina spinosa. (Norwood and Pratten.)
Reticularia setigera. (Hall.)
Composita subtilita. (Hall.)
Cliothyridina sublamellosa. (Hall.)
Eumetria vera. (Hall.)
Sulcatipinna missouriensis? (Swallow.)

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Deltopecten chesterensis. Worthen.
Schizodus chesterensis. Meek and Worthen.
Platyceras chesterense. Meek and Worthen.

It is to be noted that in the case of the Menard nearly all the names in this list occur also in the list of the Buffalo Wallow formation of Breckinridge County, Ky. For illustration see Plate 28.

BUFFALO WALLOW FORMATION.

In Breckinridge County and southward into Warren County, in the Mississippian strata above the Tar Springs sandstone, the natural sub-divisions above the same sandstone in western Kentucky and southern Illinois do not exist. Still there may be present in the said strata in Breckinridge County, etc., a representative of the Menard Limestone, as already set forth, and of the Palestine sandstone and the Clore formation. The Clore seems certainly represented by the greater part of this mass and the Menard almost certainly by a thin limestone at bottom while the Palestine sandstone may be represented in the part of the section containing thin sandstone layers, though these could with equal probability be regarded as Clore.

Owing to the circumstances just stated it is proposed to regard as a unit the Mississippian rocks above the Tar Springs sandstone in Breckinridge County and in the intervening belt along the margin of the coal field to Warren County, and give to it the name Buffalo Wallow formation. The name is from the Buffalo Wallow, a cirque-like excavation in the characteristic shales of the formation on the highway 2 miles west of Cloverport, Ky.

The Buffalo Wallow formation is made up principally of soft bluish shale but includes beds of red shale, limestone, and sandstone which altogether compose a subordinate part of the mass, the thickness of which is 150 to 200 feet.

The Menard limestone is probably represented by a layer of pure limestone 1 to 15 feet thick in the bottom of the Buffalo Wallow immediately overlying the Tar Springs sandstone. This limestone is exposed in the road southwest of Cloverport, where it is about 1 to 2

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feet thick, hard and tough, medium coarse, crystalline and bluish-gray in color. It is thicker farther south and in the valley just east of the old Victoria cannel coal mine is a thick-bedded mass apparently 15 feet or more thick. At this point it contains *Sulcatopinna missouriensis*, a fossil rarely found except in the Menard. In Warren County on the Woodbury pike between Richardsville and Riverside, there is a 20-foot bed of heavy limestone 40 feet above the Tar Springs sandstone, the intervening space being occupied with soft greenish shale. (See Section 11, Plate 3.) In Breckinridge County there is a persistent limestone horizon in the space about 70 to 90 feet above the Tar Springs sandstone. This limestone is usually somewhat impure and shaly and is highly fossiliferous, almost all of the species listed from the Buffalo Wallow being from it. Scattered limestone layers in shale occur below this horizon in places more and in others fewer. Also in the lower 60 feet of the shale are scattered layers of fine-grained greenish sandstone 1 inch to 1 foot thick.

In the section at the Buffalo Wallow 2 miles west of Cloverport there is a fossiliferous limestone conglomerate 5 feet thick 50 feet below the top (Section 26, Plate 3), and in the section on the Woodbury pike in Warren County is a similar though coarser conglomerate 80 feet below the top of the Buffalo Wallow. (Section 11, Plate 3.) In Breckinridge County in the Bowling Green road on the hilltop 2½ miles south of Cloverport, at Tar Forks church, and at the junction of the Bowling Green road with the road to Jolly, are thick-bedded, crystalline, blue limestone layers just under the Pottsville sandstone that appear to be higher beds of the Buffalo Wallow than elsewhere observed. Usually the Pottsville lies upon shale which probably underlies this upper limestone. Such a condition is to be expected owing to the fact that the Mississippian rocks had been dry land subject to erosion for a long time before the Pottsville rocks were deposited upon them. Necessarily more of the Upper Mississippian rocks were removed in some places than in others, so that the Pottsville now lies upon different beds in different localities.

The general aspect of the Buffalo Wallow rocks in outcrop and of the surface underlain by them is shown in the photographs, Plates 27A and 27B.

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PLATE 27A.
Buffalo Wallow formation 4 miles south of Cloverport. Soft, dark shale about 30 feet above the Tar Springs sandstone.

PLATE 27B.
Same locality as 27A. Shale with thin, greenish, fine-grained sandstone layers just under the shale shown in 27A.

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The fauna listed below was obtained from the Buffalo Wallow, chiefly in the fossiliferous limestone above described, 70 to 80 feet above the Tar Springs sandstone, in the vicinity of Cloverport.

LIST OF FOSSILS FROM THE BUFFALO WALLOW FORMATION.

Amplexus sp.
Triplophyllum spinulosum. Edwards and Haime.
Pentremites serrata. Ulrich. n. sp.
Pentremites pyramidatus. Ulrich.
Pentremites sp.
Pterotocrinus depressus. Lyon and Casseday.
Agassizocrinus conicus. Owen and Shumard.
Echinocrinus sp.
Spirorbis sp.
Ortonia? sp.
Fistulipora sp.
Batostomella sp.
Anisotrypa sp.
Lioclema sp.
Stenopora sev. sp.
Archimedes laxus. Hall.
Archimedes swallowanus. Hall.
Achimedes meekanus. Hall.
Fenestella sev. sp.
Polypora sp.
Septopora subquadrans. Ulrich.
Meekopora sp.
Streblotrypa nicklesi. Ulrich.
Crania chesterensis? Miller and Gurley.
Orthotetes kaskaskiensis. (McChesney.)
Productus ovatus. Hall.
Diaphragmus elegans. (Norwood and Pratten.)
Camarophoria explanata. (McChesney.)
Spirifer leidyi. Norwood and Pratten.
Spirifer increbescens. Hall.
Spiriferina transversa. (McChesney.)
Spiriferina spinosa. (Norwood and Pratten.)
Reticularia setigera. (Hall.)
Martinia sulcata. Weller.
Composita subquadrata. (Hall.)
Cleiothyridina sublamellosa. (Hall.)
Eumetria vera. (Hall.)
Hustedia? sp.
Sphenotus sp.
Allerisma clavatum. McChesney.

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Nucula sp.
Leda sp.
Sulcatipinna missouriensis. Swallow.
Myalina aff. swallowi. McChesney.
Deltopecten sp.
Bucanopsis textilis. (Hall.)
Bellerophon n. sp.
Euomphalus planidorsatus. Meek and Worthen.
Sphaerodoma sp.
Griffithides sp.

This is clearly the fauna of the Menard and Clore formations and leaves no doubt of the equivalence of the Buffalo Wallow to those formations and the Palestine sandstone included between them.

The characteristic Menard, Clore, and Buffalo Wallow fossils are illustrated on Plate 28.

FOSSILS OF THE MENARD, CLORE, BUFFALO WALLOW AND OTHER FORMATIONS.

Plate 28.

1-2 Composita subquadrata. (Hall.) This large size is very characteristic of the Menard, Clore, and Buffalo Wallow.

3-4 Spirifer increbescens. Hall. Like C. subquadrata, highly characteristic of the Menard, Clore, and Buffalo Wallow. The two occur together in the same layers.

5-7 Camarophoria explanata. (McChesney.) Common in Menard limestone.

8-9 Eumetria vera. (Hall.) Common in Clore and Buffalo Wallow, but not confined to them.

11-12 Pentremites serrata. Hambach. From upper part of Buffalo Wallow, 1 mile east of Tar Springs, 3 miles south of Cloverport. The distinctive feature is the transverse wrinkles and serrations on the margins of the interambulacral areas. Common in the Clore and Buffalo Wallow. Doubtfully identified also by Ulrich from the Golconda formation where if present, is rare.

12-14 Sulcatopinna missouriensis. (Swallow.) Gravel Creek, 3 miles northeast of Chester, Randolph County, Ill. Fairly abundant and widely distributed in the Menard limestone. Rare in Clore and Buffalo Wallow. The sections of the shell on the smoothly weathered surfaces of the limestone layers, as shown in figures 12 and 13, are most commonly seen. No. 12 is a section nearer the beak and No. 13 nearer the posterior end. No. 14 is a figure of a specimen larger than the average. Posterior end restored in outline.

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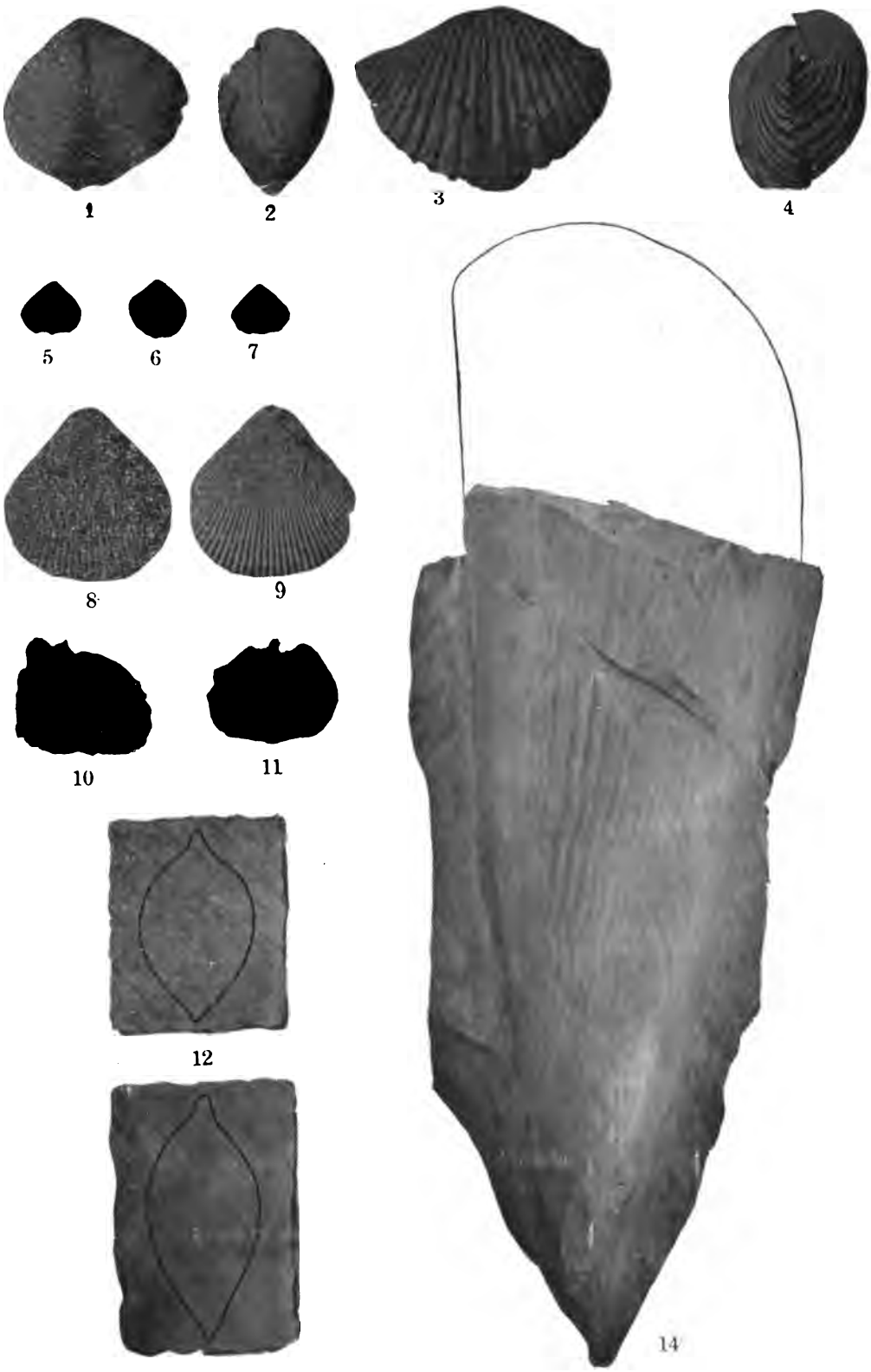

PLATE 28.
Fossils of the Menard, Clore, and Buffalo Wallow and other formations.

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UNCONFORMITY.—Any discussion of the upper Mississippian rocks would be incomplete without some attention being given to the unconformity at their top. Between the time that the last of the now present Mississipian strata of Ohio and Mississippi valleys were laid down in marine water and the subsequent time when the overlying Pottsville conglomerate, sandstone or shale was laid down upon them, a very large part of the region west of the Appalachian Valley was elevated into dry land and so remained during the intervening time. It seems that in all or most of this time deposition continued along the Appalachian Valley and eastern margin of the Appalachian Plateau and that at least 2,000 feet of Mississippian rocks younger than any in the Mississippi Valley, as for example the Parkwood formation in Alabama,* and 10,000 feet or more of Pottsville older than the oldest Pottsville of the Mississippi Valey were deposited as in the Cahaba coal field of Alabama.†

During the immensely long time, therefore, in which the great thickness of rocks just stated was being deposited, the Mississippi and Ohio valleys region was dry land subject to erosion so that hills and valleys were carved out and the surface rocks were of strata at very different stratigraphic horizons in different localities, exactly as they are on the hilly surfaces of the present time. Hence, when the region again became the arena of deposition, the upper Pottsville rocks necessarily found a resting place on an uneven surface just in fact as deposits would find at the present time were the surface submerged by water and sediments were deposited upon it. An example of this on a slight scale in Breckinridge County has already been given. Southward the Pottsville rocks rest upon lower and lower rocks and at Mammoth Cave are in contact or nearly in contact with the Cypress sandstone (Section 13, Plate 3), from which fact it follows that all the overlying part of the Chester group aggregating a known thickness of at least 400 feet had been removed by erosion before the deposition of the Pottsville. In Warren County north of Bowling Green on the Brownsville road the Pottsville

*Butts, Chas., U. S. Geol. Survey Geologic folio 175, 1910.
†Butts, Chas., U. S. Geol. Survey Bull. 431, 1911.

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rests upon a horizon in the Golconda about 70 feet above the top of the Cypress sandstone while a few miles farther west on the Woodbury pike the full thickness of the Chester as known in Breckinridge County, is present beneath the Pottsville. (Section 11, Plate 3.) It is plain that the coal measure rocks east of a line drawn from the vicinity of Leitchfield to Bowling Green were laid down in a broad depression eroded into the Mississippian strata.

POTTSVILLE GROUP (COAL MEASURES.) — The Mississippian strata of the region are overlain by coal-bearing rocks of upper Pottsville age. The basal Pottsville rocks are nearly everywhere conglomerate or coarse sandstone and in many places have near their bottom workable beds of coal. In Kentucky the presence of coal beds is almost a sure criterion of the Pottsville, since coal is of rare occurence in the Mississippian rocks. In Pope and Hardin counties, Ill., however, there are several thin coal beds in the Mississippian. The Pottsville sandstone can be generally distinguished from any of the Chester sandstones by its generally greater coarseness; by the presence in many cases of abundant mica in large flakes, which is rare in the Chester sandstones; and by the presence of quartz pebbles which have been observed by the writer in the Chester sandstones of Kentucky only in one instance, so that for all practical purposes the Chester sandstones may be regarded as entirely free from pebbles, and any pebbly sandstone or conglomerate may be accepted without further question as Pottsville.

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THE FORMATIONS OF THE CHESTER SERIES IN WESTERN KENTUCKY AND THEIR CORRELATES ELSEWHERE

BY

E. O. ULRICH

1917

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THE FORMATIONS OF THE CHESTER SERIES IN WESTERN KENTUCKY AND THEIR CORRELATES ELSEWHERE.

By E. O. Ulrich.*

PART I. INTRODUCTORY CHAPTERS.

INVESTIGATIONS OF CHESTER FORMATIONS IN WESTERN KENTUCKY.

Early Investigations by the Author in Western Kentucky.—In October, 1888, I was employed by the State Survey of Kentucky to determine and map the geological formations in the lead and fluorspar district of western Kentucky. The area to be mapped comprised the counties of Caldwell, Crittenden, Livingston, and Lyon, with such parts of Trigg and Christian counties as might be deemed desirable. The following November and part of December were spent in a general reconnaissance of the district. This showed clearly that the region is profusely faulted and the formations not only largely different from what had been supposed, but also variable in character and sequence from place to place. Nevertheless, sufficient progress was made in the way of detailed local sections and collections of fossils to enable me to construct a working sequence of beds and faunas.

With this as a basis, I returned to the field in the following May and continued there until November. More than four months of this season were devoted to detailed mapping in Caldwell and Crittenden counties, the remaining six weeks being spent in necessary visits

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to other nearby areas that promised to throw light on difficulties encountered in the proper classification of the observed stratigraphic units. One of these side trips was made with J. M. Nickles to western Illinois. Beginning in the Pennsylvanian at Sparta, we drove to Chester, and thence up the Mississippi bottom along the classic bluff exposures of the Mississippian rocks to Columbia.

The close of the field season of 1889 was followed by 10 months of close study and comparison of fossils and notes gathered in the course of the work. And then two more months—October and November of 1890—were spent in Crittenden County in the hope that reports on this and Caldwell County might be completed during the winter and submitted for publication by the State. Unfortunately, however, the State Survey died for lack of appropriations before either of the reports could be completed.

Other pursuits necessitated abandonment of these Mississippian studies during the following 12 years when, by a co-operative arrangement between the State—acting for subscribers resident in the district—and the United States Geological Survey, work was resumed in western Kentucky and southern Illinois, and this time pushed to the stage of completion presented in U. S. Geological Survey Professional Paper 36 and Bulletin 267. Thus another field season—that of 1902—and a part of the season of 1903, were devoted to the study of chiefly the Chester part of the Mississippian in Kentucky and Illinois. All told I spent 15 months in the field and an additional three years in office studies before submitting the manuscript for Professional Paper 36.

Moreover, prior to 1888, I had familiarized myself with the Upper Mississippian or Tennessean rocks and faunas in southern Kentucky and in Grayson County of the same State, and also with faunas of similar age in Illinois, particularly the Bryozoa, than which no class of fossils is better for correlation purposes. Finally, between the close of field work in western Kentucky and the completion of the manuscript for Professional Paper 36, I studied and revised the classification of the Chester deposits in northern Arkansas. The results of these in-

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vestigations are given in U. S. Geological Survey, Professional Paper 24.

Part of the manuscript prepared for Professional Paper 36 consisted of a long chapter on general and detailed correlations of Mississippian formations in eastern United States. Unfortunately, perhaps, it was decided, before sending the manuscript to the printer, to eliminate this chapter from the report on western Kentucky and to save the matter for a more strictly stratigraphic work on the Paleozoic section in the Mississippi Valley, then comtemplated but never completed.* However, as the present paper is based almost entirely on data collected in the course of investigations made before the completion of the published manuscript, it may be said to be an amplification of the discarded chapter.

RECENT WORK IN KENTUCKY AND ILLINOIS.—Since the publication of Professional Paper 36 in 1905, Prof. Stuart Weller has spent a number of seasons in field studies of the Mississippian rocks in the Mississippi Valley. A preliminary paper, giving the main results of these investigations in so far as the Chester series is concerned, was published by him in 1913.† In this paper Professor Weller tacitly rejects Ulrich's proposal to include the Ste. Genevieve in the Chester. Doubt also is expressed as to the applicability of Ulrich's classification to the section in Illinois. However, the real purpose of the paper is the description and naming of "a series of nine distinct formations in the Chester group." Altogether it is a most valuable contribution to the subject. Indeed, it marks a new departure in that the separation of the series into small formations supplied the means of gaining a much truer conception of Chester stratigraphy than was possible before.

Following the publication of this paper, Professor Weller continued his investigations of the Chester, parts of the field seasons of 1914 and 1915 being devoted chiefly to reconnaissance study of the rocks of this series in southern Illinois and western Kentucky. In this later work he was at times associated with G. H. Girty, Char-

*See note p. 24 in U. S. Geol. Survey, Prof. Paper 36.

†Weller, Stuart, Stratigraphy of the Chester group in southwestern Illinois. Illinois Acad. Sci. Trans., Vol. 6, pp. 118-129, 1913.

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les Butts, and Wallace Lee of the United States Geological Survey.

Mr. Butts independently devoted also large parts of 1915 and 1916 to field study of Chester formations in southern Illinois and western Kentucky. His work in the latter State is particularly important because it traced the formations from the Ohio River in Breckinridge and Meade counties around the southern border of the coal field and thus back again to the river in Crittenden County where it joined the more detailed investigations carried on by him and Mr. Lee in Hardin County, Ill. The results of this work are presented in Mr. Butts's contribution to this volume. So far as questions of correlation are concerned, the most important feature is the verification of Ulrich's previously published views regarding the identity of the sandstones capping Downeys Bluff at Rosiclare, and Cedar Hill near Princeton, and the relations of this sandstone to the underlying Ste. Genevieve limestone and the overlying Gasper ("Tribune") oolite.

Finally, in 1916 a field conference of interested geologists comprising Messrs. Weller, Girty, Butts, Ashley, DeWolf, and the writer was arranged, and two weeks were spent in a review of Chester stratigraphy in Illinois, Missouri, and Kentucky. All of these later studies added more or less of new and in part detailed information that is essential to a satisfactory conception of the distribution and geologic history of the Chester series in eastern United States.

EFFECT OF RECENT STUDIES ON ULRICH'S CLASSIFICATION OF 1905.

GENERAL STATEMENT.—It is perhaps impossible to say the "last word" on any subject. Errors of observation and deduction are sure to creep in. It is, therefore, but natural that such errors should invalidate at least parts of the classification published by me in 1905. The subject at its best is difficult; and the faulted character of the region in which the sequence and classification of the beds was mainly worked out made the difficulties all the greater. Besides, one often is obliged to accept erroneous preceding or contemporaneous obser-

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vations and opinions of other workers in the same areas. Verification before acceptance is not always practicable.

The stratigraphic part of Professional Paper 36 contains many errors. However, I am glad to add that so far as I have learned, the mis-statements, with a few exceptions, are confined to relatively unessential matters. Most of these I have observed in the meantime for myself; others have been disclosed mainly through the investigations of Butts and Weller. Doubtless others yet remain to be detected.

Viewed from the standpoint of present knowledge, the recent work by Weller and Butts in southern Illinois and western Kentucky has necessitated little more than merely nomenclatural changes in the classification of the Chester series published by me in 1905 and, with emendations, in 1910.* Some of the correlations in the latter are not strictly in accord with present views, the Maxville limestone of Ohio in particular being placed too low. Judging from its *Pentremites*, this limestone should be correlated with the Gasper oolite, or "Tribune" limestone, as it was then called.

The sequence of Chester beds in Kentucky given in Professional Paper 36 is really nearer the truth as now considered than would appear from criticisms that have been made in recent years. This old classification recognized the identity of the sandstones capping Cedar Hill, near Princeton, and Downeys Bluff, at Rosiclare, Ill. And with this fact as a guide it was readily possible to determine the sequence for the lower or Monte Sana part of the series. Even the much more difficult Birdsville sequence is clearly enough indicated, particularly in the generalized section of the Chester on page 38. Quoting from this, the sequence of lithologic units of the Birdsville as then understood is as follows:

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*Ulrich, E. O. Revision of the Paleozoic systems. Geol. Soc. America Bull., Vol. 22, Pl. 29, 1911.

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Birdsville Formation.

	Feet.
Flinty limestone at top	20
Arenaceous shales above, hard, dark limestone and soft clayey shales below	0–105
Dark shale above and sandstone in two beds (Palestine and Tar Springs sandstones) alternating with two beds of limestone (Menard and Glen Dean limestones) below	116–220
An extremely variable series of shales, sandstones and limestones, the last usually aggregating but a small part of the whole (Hardinsburg sandstone, Golconda formation and Cypress sandstone)	225–350

The parenthetical insertion of the rather obvious equivalents of the described beds in the more detailed classification proposed by Weller and now adopted in Kentucky shows at once that the structural difficulties of the field were not sufficient to prevent the determination of the sequence of beds. The difficulty that worried me most in my early work in Kentucky was not the identification of the broken and dissociated beds, but to draw anything like satisfactory boundaries between the extremely variable lithologic units. The fossils, and to some extent the lithologic features, served the former purpose as well then as today; but the lateral passage of massive sandstones into shale, or their apparent reduction from thicknesses of 60 feet or more to less than 20 feet in a few miles raised many perplexing questions. And the latter difficulties are hardly less today in the Birdsville part of the series than formerly. Fortunately, difficulties of this kind were encountered in the lower or Monte Sana division of the series only in the northwestern half of the field. In Caldwell and adjoining counties to the southeast, this part of the section consists mainly of profusely fossiliferous limestones, with easily distinguishable zones; and intercalated in these at fairly regular intervals are the two sandstones, the Rosiclare below and the Aux Vases above, which could not be confused.

However, in the broad area lying to the northwest of the Marion fault and stretching thence across the Ohio over the southern tier of counties in Illinois, the unsuspected lateral transition of the Gasper oolite into

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the Ridenhower shale occasioned widely ramifying misapprehensions, some of which have only very recently been corrected. The matter is discussed at sufficient length in the chapter on stratigraphy. However it seems desirable to refer briefly here to one of the errors that would have been avoided if I had understood the relations of the Ridenhower to the Gasper.

THE NAME "TRIBUNE" LIMESTONE—ABANDONED.—Persuaded by the unfounded belief that the Gasper oolite maintains, and indeed increases, its thickness in a northwesterly direction from the typical outcrops in Christian and Caldwell counties, the limestone outcrop at Tribune, in Crittenden County, Ky., was wrongly identified with this formation when the maps in Professional Paper 36 were being prepared. Subsequently, when a name for the limestone overlying the Aux Vases sandstone became necessary and no other appropriate and at the same time unused name seemed available, the term Tribune limestone was suggested and adopted. Now that it is certain that the limestone at Tribune is the same as the Menard limestone in Illinois, and as it is still desirable to distinguish the older limestone in Caldwell County as a separate formation, it has been decided to abandon the name "Tribune" in favor of a new term. Accordingly, Mr. Butts proposes Gasper oolite to take its place, a proceeding that meets my approval.

THE SUPPOSED LIMESTONE MEMBER OF THE "CYPRESS" SANDSTONE.—Though the misapprehensions just referred to affected the identification of beds commonly very closely associated with the main sandstone of the Lower Chester, namely, the Aux Vases or, as I formerly called it, the "Cypress" sandstone, they never occasioned confusion of this sandstone with any other sandstone in the areas of western Kentucky studied by me. Though described and mapped under a name to which it held no true title, the bed itself was consistently identified throughout its extent in Kentucky. Nevertheless my description of this sandstone contains an error, the elimination of which we owe to the careful investigation of Charles Butts. As described by me in 1905 the

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"Cypress" sandstone is said to contain locally a lens of limestone some 60 to 80 feet beneath the top. Mr. Butts failed to find any evidence of such a condition at localities cited by me. On the contrary, his study of the exposures at these localities proves to my entire satisfaction that what I thought was a lens in the sandstone formation is in fact the siliceous limestone bed commonly found at the top of the underlying Ohara in Caldwell and Crittenden counties, Ky., and in Hardin County, Ill.

As will be shown presently, the term "Cypress" was misapplied by me in 1905 and 1910. This name really belongs to the younger sandstone formation that in the former publication is referred to as bed No. 1 of the Birdsville formation. But I am not primarily responsible for this error, it having been previously committed by Engelmann and Worthen in their section of Downeys Bluff at Rosiclare, Ill.

THE TERM CYPRESS SANDSTONE.—Much confusion came about through my erroneous application of the term Cypress to the persistent sandstone lying between the top of the Ohara and the base of the Gasper oolite in the eastern part of Caldwell County and the northwestern part of Christian County. In Crittenden and Livingston counties, and to the north of these in southern Illinois, the position of the Gasper is occupied by the Ridenhower shale so that in this area the sandstone referred to is overlain and separated from Bed 1 of the Birdsville by a body of more or less calcareous shale instead of a limestone. The relations of the Ridenhower shale to the Gasper oolite will be discussed on following pages.

The typical exposures of the Cypress sandstone are in Union and Johnson counties, Ill. It was here studied in the early sixties of the last century by Engelmann* who proposed the name from Cypress Creek, along which he had observed good exposures. In Engelmann's classification of 1862 (op. cit.) the Chester is divided into 10 beds, these being numbered from above

*Engelmann, Henry. St. Louis Acad. Sci. Trans., Vol. 2, p. 189, 1868. (Paper read Nov. 3, 1862.)

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downward, the odd numbers standing for beds consisting of limestone or of more or less calcareous shale and shaly limestone, the even numbers for the intervening sandstones. Of these only one, No. 8, was given a geographic designation, namely, Cypress sandstone. This name was not used in the official reports of the Geological Survey of Illinois; nor was it adopted by any other author until 1905 when it was revived by Ulrich for the sandstone overlying the Ohara.

Engelmann and Worthen* identified the sandstone at the top of Downeys Bluff with No. 8 of Engelmann's generalized section of the Chester in southern Illinois. In the same volume the sandstone in Johnson County, Ill., for which Engelman† had proposed the name Cypress, also is referred to No. 8. Further, it is to be observed that Engelmann (op. cit. p. 189) regarded No. 8—Cypress sandstone—as probably "a more fully developed equivalent of the Ferruginous sandstone of the Missouri Geological Report." Also that in 1892 Keyes proposed the geographic name Aux Vases sandstone to replace the lithologic designation "Ferruginous sandstone." In 1905, then, after two visits to the Mississippi Valley in which I convinced myself of the identity of the Aux Vases sandstone with the sandstone capping Downeys Bluff, and having assumed the correctness of Engelmann's identification of both of these sandstones with the Johnson County sandstone to which he had applied the name Cypress sandstone, no other consistent course was open to me than to discard the newer term Aux Vases in favor of the older term Cypress. And thus, starting with the sandstone on Downeys Bluff, the name Cypress was consistently carried through western Kentucky.

In a paper read by Professor Weller in 1915 before the Geological Society of America, but yet unpublished, evidence is presented showing that the sandstone No. 8 in Johnson County, Ill., is not the same but a younger deposit than the Aux Vases sandstone of Ste. Genevieve County, Mo. This conclusion was corroborated by the

*Worthen, A. H., and Engelmann, Henry. Report on Hardin County. Illinois Geol. Survey, Vol. 1, p. 256, 1866.

†Engelmann, Henry. St. Louis Acad. Sci. Trans., Vol. 2, p. 189. (Paper read Nov. 3, 1862, published 1868.)

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work of the field conference in 1916. The facts in the case are as follows:

In the vicinity of Ridenhower, Ill., which may be properly included in the typical area of the Cypress, Engelmann describes two Chester beds beneath this sandstone. The upper he called No. 9, the lower No. 10. The last is a sandstone, here but 10 feet thick, hence greatly inferior in volume to No. 8 (the Cypress) which caps the hills in this vicinity. No. 9, here about 50 feet thick, consists mainly of shale interbedded, especially in its lower part, with limestone. It contains a considerable fauna clearly indicating the horizon of the Paint Creek beds to the northwest in Monroe County, and that of the middle and upper members of the Gasper oolite to the southeast in Christian County, Ky. Beneath No. 10 is a limestone, including both oolitic and crystalline ledges, shown to a depth of about 12 feet. In Engelmann's section this underlying limestone is referred to the St. Louis. (Weller correlates it with his Renault formation and with the upper part of the Ohara member of the Ste. Genevieve). In my opinion it represents the upper Ohara (but not the Renault which I regard as absent here). As interpreted by me the section near Ridenhower, Ill., is as follows:

Ulrich's interpretation of Englemann's, and recently Weller's section on Cache River, near Ridenhower, Johnson County, Ill.
(Verified by conferees in August, 1916.)

		Feet.
5.	Sandstone, massive, rather coarse, at top of ridge, identified by Engelmann with Division No. 8 of his classification of the Chester series	30
4.	Limestone and shale, probably mainly shale, fossiliferous, identified by Engelmann with his Division No. 9	50
3.	Sandstone, massive and soft in upper part but harder and irregularly thin-bedded in lower half, identified by Engelmann with his Division No. 10	10–20
2.	Unfossiliferous, arenaceous, in part conglomeratic limestone, its base in uneven contact with underlying bed 1 of section	1-2
1.	Limestone, fossiliferous, oolitic or crystalline, much of it cross-bedded, light-gray, referred to the St. Louis limestone by Engelmann, and to the upper part of the Ohara member of the Ste. Genevieve, which is said to correspond to the Renault limestone of Monroe County, by Weller, exposed	12

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Bed No. 1 of this section unquestionably belongs to the Ohara member of the Ste. Genevieve. It is certainly not St. Louis, as supposed by Engelmann, nor is it Renault, as supposed by Weller. Its fossils, among them *Pentremites princetonensis* in abundance, establish its age beyond all doubt as Ste. Genevieve, and apparently no less definitely as upper Ste. Genevieve.

Bed No. 2 also may be Ohara, but a more probable interpretation would make it the initial deposit of the succeeding sandstone.

Bed No. 3 is the Aux Vases sandstone, here reduced in thickness. Accordingly it corresponds to the sandstone capping Downeys Bluff at Rosiclare, Ill., and Cedar Hill, near Princeton, Ky., and also to the lower sandstone in the Ohio River bluff just below Golconda.

Bed No. 4 is what the conference of 1916 agreed to call Ridenhower shale. In Crittenden County, Ky., the southern extension of the Ridenhower passes laterally into more or less shaly limestone that represents the westwardly overlapping upper part of the Gasper oolite. Compared with the section in Randolph and Monroe counties, Ill., the Ridenhower shale corresponds to parts or the whole of the sequence there divided into Yankeetown chert, Paint Creek formation, and Ruma formation.

Bed No. 5 is the typical Cypress sandstone. In Kentucky this corresponds to the Big Clifty sandstone of Kentucky authors, and to Bed 1 of Ulrich's Birdsville formation. Arguments are given in this paper favoring correlation of the Cypress sandstone with the main or typical mass of the Okaw limestone of the Mississippi Valley.

Essentially the same sequence is found in the Ohio River bluff below Golconda, the Cypress forming the greater upper part of the bluff at the lower edge of the town. No. 9, here less calcareous than in the Johnson County locality, rises gradually from the bottom to the top of the bluff, the thickened lower sandstone, No. 10, then being shown beneath it, until finally, about 2 miles below Golconda, the top of the underlying limestone emerges from the bed of the river. And the same se-

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quence is again exposed in the rising north limb of the syncline above the mouth of Grand Pierre Creek.

After crossing the faulted and downthrown strip between Grand Pierre Creek and Rosiclare, about 4 miles wide along the Ohio, the lower sandstone, No. 10 of the section in Johnson County, with the same *Lyropora*-bearing limestone under it that had previously been noted in the bank of the river just above Grand Pierre Creek and again below Golconda, is unquestionably recognized in the sandstone capping Downeys Bluff. Engelmann and Worthen, however, failed to recognize this Downeys Bluff sandstone as their No. 10 in the Johnson County section. On the contrary, they describe it as No. 8.

This confusion of Nos. 8 and 10 evidently arose from three circumstances. First, there is in Downeys Bluff another, yet lower sandstone—the Rosiclare sandstone member of the Ste. Genevieve—that is either wanting or concealed in the Johnson County sections studied by these observers. Second, the fauna of the limestone, and especially of the shaly beds in the interval between the Rosiclare sandstone (which Engelmann and Worthen thought to be No. 10) and the top sandstone (believed by them to be No. 8), is so much larger and more obviously Chesterian in aspect than is the fauna of the limestone beneath the sandstone No. 10 in the Johnson County section that the essential equivalence of the two was not recognized by them. Third, they failed to observe that the interval between the base of the Golconda shale and the top of the Ohara limestone in the Ohio bluffs between the mouth of Grand Pierre Creek and Golconda is occupied by two sandstones with the Ridenhower shale between them, and not, as they supposed, by a single sandstone formation. (See table and cross-section on a succeeding page.)

The fact first pointed out by Butts in the field conference of 1916, that in the Ohio River bluffs below and above Golconda the stratigraphic interval between the base of the Golconda Shale (the *Pterotocrinus capitalis* bed) and the top of the underlying Ohara limestone is not a single sandstone unit but a tripartite series composed of two wholly distinct sandstones with a consider-

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able thickness of shale between them, is of extraordinary significance. This important discovery completely negatives my former (1905) determination of the age of the sandstone immediately overlying the *Talarocrinus*-bearing upper Ohara limestone in the Ohio River bluffs as Cypress. The sandstone capping Downeys Bluff at Rosiclare also can not be the Cypress. On the contrary, it corresponds to Englemann's No. 10 in the Cache River section; and the same is true of the lower sandstone in the Bluff above the mouth of Grand Pierre Creek, where it similarly rests on the *Talarocrinus* bed of the upper Ohara.

In both of the latter instances this sandstone is succeeded by a thick bed of shale which the members of the field conference of 1916 recognized as corresponding to Engelmann's No. 9 in the Cache River section and for which it was agreed to adopt the name Ridenhower shale. In the Ohio bluffs, as on Cache River, the Ridenhower is succeeded by the sandstone which alone has a right to bear the name Cypress sandstone.

Further, with the data now in hand, it is clearly established that the terms Cypress and Aux Vases sandstones are not, as I believed in 1905, synonymous. The true Cypress sandstone being the introductory sandstone of the Birdsville formation or, more properly, Birdsville group, some other name must be applied to the lower bed erroneously termed Cypress by me in 1905.

Here it is to be remembered that I had never questioned the identity of this lower sandstone with the Aux Vases sandstone of Missouri. As intimated, and disregarding the then possible interference of the term Big Clifty sandstone,* my only reason for not using the name Aux Vases was the mistaken acceptance of Engelmann's correlation of the Johnson County No. 8 (Cypress sandstone) with the "Ferruginous sandstone" of

*Information available in 1905 concerning the Big Clifty indicated that it corresponded in position and character to the Aux Vases. At that time, however, I was unaware of the fact that the Aux Vases pinches out of the section east of Christian County and that in eastern Todd, Logan, Warren, and Edmonson counties the first of the massive Chester sandstones is no longer the Aux Vases but a younger bed, namely, the typical Cypress, to which also the sandstone at Big Clifty belongs. These conditions were obscurely realized by me in 1906 but the credit for their complete proof belongs to Mr. Butts.

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Missouri (now the Aux Vases sandstone) on the one side, and the "No. 8" sandstone of Downeys Bluff on the other. My personal convictions in the matter were founded entirely on field comparisons of the Downeys Bluff section and similar sections in western Kentucky with the section in Ste. Genevieve County, Mo., including the typical outcrop of the Aux Vases sandstone, and as my views on the relations of these sandstones have not changed, it follows that my acknowledged error concerning the sandstone mapped and described in Professional Paper 36 under the name Cypress is a nomenclatural one only. Starting from an erroneous conclusion by others, I made matters worse by selecting the wrong name of two that were supposed to be synonymous.

Henceforth, therefore, it is to be understood that when I use the name Aux Vases sandstone in speaking of rocks in Kentucky and southern Illinois I am referring to the bed previously designated by me as Cypress sandstone; and when I say Cypress sandstone I mean Bed 1 of the Birdsville in my 1905 classification.

THE BIRDSVILLE FORMATION OR GROUP AND ITS SUBDIVISIONS.—Regarding the 11 Chester beds above the typical Cypress sandstone which, together with this sandstone, were included in my Birdsville formation, I am quite ready to admit that their sequence, as given on page 61 of Professional Paper 36, may not be entirely correct. This admission, however, concerns only Beds 3 to 5 inclusive. The representative of Mr. Butts's Hardinsburg sandstone was included in the upper part of Birdsville Bed 2, but the greater lower part of this bed undoubtedly is the same as the Golconda formation of Mr. Butts's sections. If there is no mistake about the position of Bed 3, then it, together with Bed 4 about which there is little or no question, corresponds to the "Sloans Valley" or Glen Dean formation of the west-central and southern Kentucky sections. In that case, Bed 5, which was recognized at only a few places in western Kentucky, must be the thinning westerly extension of the Tar Springs sandstone. Correlated with Weller's Illinois section, Bed 6 is the Menard lime-

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stone, Bed 7 evidently the Palestine sandstone, and Beds 8 to 12 successive zones of the Clore formation.

RECENT DIFFERENCES IN CORRELATING CHESTER FORMATIONS.—In the past few years it has been claimed that there is no such formation as the one described by me in Professional Paper 36 under the name "Tribune" limestone. It has also been claimed* that what I called the Ohara member of the Ste. Genevieve limestone embraces representatives of two widely distinct formations. These are said to be separated by a most important unconformity or stratigraphic break, marking, indeed, the boundary between the Meramec and Chester series of the Mississippian and the position of the supposedly absent Aux Vases sandstone. The part above the "great break" is said to correspond in age to the Renault formation recently named from exposures in Monroe County, Ill., by Professor Weller.†

In the following chapters I shall endeavor to present the facts as fully as I know them. Each set of facts is then discussed separately with a view to settling questions on which differences of opinion might arise or have already arisen. These questions have been most carefully and fairly considered and the following conclusions reached: (1) That the "break" between the upper and lower parts of the Ohara has no such importance as has been attributed to it; (2) that the so-called "Upper Ohara" is not the equivalent of any part of the Renault but a distinctly older pre-Aux Vases deposit; (3) that the real equivalent of the Renault is included in the Gasper oolite ("Tribune" limestone of Caldwell (not Crittenden) County); (4) that the Gasper oolite corresponds not only to the Renault formation but also to the Yankeetown chert and the Paint Creek and Ruma formations which overlie the Renault in Monroe and adjoining counties in Illinois, and finally (5) that historically, faunally, and structurally, taking the country as a whole, the best and most convenient boundary between the Meramec and Chester series is to be drawn at the base of the Ste. Genevieve limestone.

*Weller, Stuart, Contr. Walker Mus., Vol. 1, p. 243, 1916.
†Weller, Stuart, Illinois Acad. Sci. Trans., Vol. 6, p. 122, 1913.

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THE BASE OF THE CHESTER SERIES.

CLASSIFICATION AND AGE OF THE STE. GENEVIEVE LIMESTONE.—Professor Weller objects to my proposition to include the whole of the Ste. Genevieve in the Chester group or series. He does not accept my statement that the fauna of the Ste. Genevieve is a unit and as a whole more closely related to that of unquestioned parts of the Chester than to that of the Meramec formations. Regarding this point he maintains that the fauna of the Ohara member is dual in composition, the fossils in the upper part being clearly Chesterian in character whereas those in the lower part, like those in the underlying Fredonia members, are quite as definitely affiliated with the Meramecian. Further, he rejects my conclusion that the whole of the Ste. Genevieve in western Kentucky and southern Illinois, including the "upper Ohara," is older than the Aux Vases sandstone. On the contrary, he claims that the "upper Ohara" is of the age of the Renault formation which overlies the Aux Vases sandstone in the Mississippi Valley. Finally, in consequence of this correlation he finds it necessary to assume an important stratigraphic hiatus in the midst of the Ohara. This supposed hiatus includes the Aux Vases sandstone which he believes to be absent in western Kentucky, but which I recognize in the sandstone between the top of the Ohara limestone and the base of the Gasper oolite.

The discussion of the faunal and structural features of the evidence bearing on these disputed questions will be found on succeeding pages of this work. Here we shall look into the historical part only.

THE HISTORICAL PART OF THE EVIDENCE RELATING TO THE CLASSIFICATION OF THE STE. GENEVIEVE.—In the first place, it is important to learn when and where Engelmann first observed the conditions that finally induced him to include older beds than the Aux Vases sandstone in the group or series to which Worthen subsequently applied the term Chester. Prior to his investigations in southern Illinois, the base of the Aux Vases sandstone must have appeared to him and his contem-

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poraries to be the boundary most obviously indicated in the Mississippi Valley proper. That he regarded Chester deposition in southern Illinois as greatly superior in volume and time represented to that found in Monroe and Randolph counties in western Illinois and in nearby areas in southeastern Missouri is clearly indicated in the short paper on the "Lower Carboniferous system" in southern Illinois, read for him by Shumard in November, 1862, and published in 1863.* The context of this paper further established that the generalized information therein contained, especially as concerns the Chester group and its subdivisions, was not acquired only in Johnson County, but that it represents the combined results of a season's work in an area embracing also parts of Union, Pope, and Hardin counties.

When we take into consideration the full reports on these investigations by Engelmann, published four years later (1866) in Volume 1 of the Geological Survey of Illinois, comparison strongly suggests that his study of at least the lower part of the Chester series was carried out in greater detail and with more satisfaction to himself in Hardin County than in the others. This is indicated primarily by the fact that Hardin is the only one of the four or more counties in which he had worked in 1862 of which a geological map was prepared and published by him. It is suggested again by the apparent fact that throughout this county he was never in doubt as to the recognition of the bed which he called No. 8, for it constituted the upper of the three beds—Nos. 8, 9, and 10, comprised in his "Lower division of the Chester formation"—which he mapped separately from the upper division.

It seems likely that Worthen and Engelmann began their work in southern Illinois at Rosiclare because Worthen at the time particularly desired to publish Norwood's report on the mines in that vicinity with proper stratigraphic setting. It was here, then, that Engelmann would have seen the sandstone that subsequently, in the less faulted region of Johnson County, he erroneously correlated with the younger sandstone

*Engelmann, Henry, St. Louis Acad. Sci. Trans., Vol. 2, pp. 188-190, 1863-8.

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there designated as No. 8 and named from its outcrops on Cypress Creek. It must have been in Hardin County, too, that he got his impression that No. 8 corresponded to the "Ferruginous" (now Aux Vases) sandstone of Missouri. I also became convinced of this correspondence when, after becoming acquainted with the Hardin County No. "8," I had an opportunity to study the Aux Vases sandstone in the area from which it was named. But I never would have thought of such relations for the Johnson County No. 8 sandstone, which I saw for the first time in 1916.

Engelmann fell into the error of confusing the two sandstones Nos. 8 and 10 in Hardin and Johnson counties for precisely the same reason that subsequently misled other workers in this area, namely, whereas the identification of the top of the typical Cypress (No. 8) largely depended on and was in fact made easy by the unmistakably characteristic fauna of No. 7 (which we are now calling Golconda shale), it was a much more difficult matter to determine where the base of No. 8 should be drawn in the Ohio River bluffs. In going down the river from Rosiclare to Bay River bottom, the Chester strata form a broad syncline with the Golconda shale descending in part beneath water level. The rising east and west limbs of the syncline expose thick beds of sandstone that form prominent bluffs. Engelmann estimated the thickness of these sandstones at about 250 feet; and he believed all of this to belong to his Cypress sandstone. Beneath these sandstones is a limestone which rises a few feet above lower water level in both limbs of the syncline and is precisely the same in character in both places. Engelmann determined the exposure of limestone below Golconda as corresponding in age to his Chester Division No. 9 in Johnson County, but seems not to have seen the exposure above the town.

Now, had Engelmann climbed the bluff below Golconda, as the conferees did in 1915, he would have seen that the supposed 250 feet of sandstone is not a single lithologic unit. On the contrary, he would have observed that it consisted of three divisions, a lower and an upper sandstone, with a calcareous shale between them. Further, he would have recognized the middle

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shale as the true representative of his Johnson County No. 9,* and the lower sandstone as his Johnson County No. 10. Incidentally, too, he would not have found it necessary to explain† the lithologic differences that distinguish the supposed No. 9 in Pope County from the beds described as No. 9 in the report on Johnson County. Nor would he have felt the false necessity of concluding that the "sub-Cypress Chester beds" (Nos. 9 and 10) are only locally developed in southern Illinois. On the contrary, he would have recognized that the supposed more highly calcareous Pope County facies of No. 9 is in fact the same bed that in Johnson County underlies the sandstone No. 10, and in Hardin County (particularly in Downeys Bluff) underlies the sandstone there designated as No. 8. Moreover, he would have avoided the correlation of the Rosiclare sandstone with the Johnson County No. 10, the sandstone 100 feet above the Rosiclare in Downeys Bluff being the true No. 10. Finally, he would have realized that instead of 10 alternating sandstone and limestone divisions in the Chester of southern Illinois, there are really 12 such divisions.‡ These errors in correlation and sequence of beds are shown graphically in the accompanying table and structural sketch.

*Illinois Geol. Survey, Vol. 1, pp. 380, 397, 1866.

†See Geology of Illinois, Vol. 1, p. 459, last par., p. 460, first par., 1866.

‡Except for this easily made but far-reaching error, it is but justice to say that as a rule I found Engelmann's stratigraphic determinations exceptionally reliable.

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Stratigraphic sequence and correlations of lower Chester Formations in Southern Illinois and in Kentucky west of Caldwell County.

Engelmann, Johnson Co., Ill., 1862-6.	Ulrich, 1917.		Conference of 1916: Ohio River bluffs, Pope and Hardin cos.	Engelmann and Worthen, Ohio River bluffs, Pope and Hardin cos., 1862-6.
Div. No. 7	Golconda formation		Golconda formation	Div. No. 7
Div. No. 8 Cypress ss.	Cypress sandstone		"Upper sandstone" (typical Cypress ss.)	Div. No. 8
Div. No. 9	Ridenhower shale (Upper division Gasper oolite)		Shale	
Div. No. 10	Aux Vases sandstone (Bethel sandstone)		Lower sandstone	
St. Louis ls.	Ste. Genevieve	Ohara limestone	Ohara ls. Upper / Lower	Div. No. 9
		Rosiclare ss.	Rosiclare ss.	Div. No. 10
		Fredonia oolite	Fredonia oolite	St. Louis ls.

Table showing error made by Engelmann (1862) in correlating sandstones in Johnson County with other sandstones in Hardin and Pope counties.

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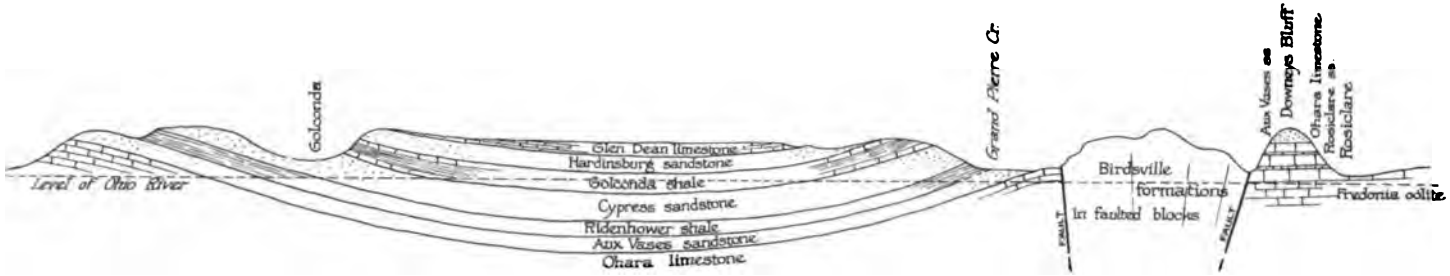
PLATE A



Sketch showing Chester formations in bluffs along Ohio River between Golconda and Rosiclare, Ill.

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Although the numbering of the Chester beds by Engelmann was chiefly determined by his investigations in the relatively unfaulted exposures in Johnson County, it nevertheless seems a fact that his conception of the Lower Division of the Chester group was based mainly on his observations in Hardin County. In other words, the abundant fossils found in the Ohara near Rosiclare had fully convinced him of the propriety of classifying the beds beginning with the Rosiclare sandstone as Chester rather than St. Louis. Accordingly, then, the application of the designation No. 10 in Johnson County merely signified his belief that the beds so designated corresponded to the Rosiclare sandstone which, in his mind, probably represented the type of No. 10. That he did not regard the Johnson County development of Divisions Nos. 9 and 10 as the best and most complete known to him is evidenced by comparative references to their greater development in Hardin County. (See particularly the last paragraph on p. 459 of vol. 1, Illinois Geological Survey).

That the Chester element in the Ohara fauna as developed particularly in Hardin County is strong enough to have induced Engelmann to include this upper member of the Ste. Genevieve limestone, together with its sandy base—the Rosiclare member—in the Chester series is beyond dispute. The same evidence subsequently proved no less convincing to me and, so far at least as the upper 60 feet is concerned, also to Weller. The latter, indeed, believes that the Ohara fauna includes species indicating not only basal Chester but supra-Aux Vases Chester.

Considering the above facts and probabilities and the entire absence of evidence tending to the contrary, it seems practically certain that the Hardin County sections and not those in Johnson County are to be regarded as typical of Engelmann's "Lower Division of the Chester group."

It is now in order to recall the fact that Worthen, the author of the term Chester group, agreed with Engelmann in referring both the Ohara limestone and the Rosiclare sandstone to the Chester series. Worthen's attitude on this matter is indubitably expressed in his

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comments on the section of the bluff (Downeys) just below Rosiclare.* In this section bed No. 1 is the capping of Aux Vases sandstone and No. 5 the Rosiclare sandstone. Worthen says: "The upper part of this section from Nos. 1 to 5 inclusive, belongs to the Chester group, and constitutes what Mr. Engelmann calls the lower division of the group, and is distinguished on the map by a different shade of color."

In view of the foregoing quotation it may be accepted as proved beyond question that in 1866, the date of the volume which contains also the description of the Randolph County section and the first definition of the term as a group, Worthen's conception of the Chester group as developed in Illinois included the two upper members of the Ste. Genevieve. In other words, it is proved that Worthen, the same as Engelmann, then drew the base of the Chester in southern Illinois at the top of the Fredonia oolite member; but there is evidence showing that the consequences of this action were not clearly appreciated by him.

As we know, Worthen was primarily a paleontologist, with the limitations and prejudices that affected the stratigraphic determinations of geologists forced to depend on the relatively imperfect knowledge of historical geology then available. At Rosiclare the faunal data in hand were quite sufficient to satisfy him of the Chester age of the Ohara and the Rosiclare sandstone, if, indeed, he did not regard it as representing the Aux Vases sandstone—was added to the group to give it the desired clastic base. The Fredonia fauna, as such, was little known to him. Besides, recurrences of faunas were not contemplated at that time, so that the strong Spergen element in the Fredonia fauna made it impossible for him to conceive of a bed holding such fossils as possibly of Chester age. Therefore, with the probable exception of the outcrop near Waterloo which he first believed to be Chester, the main body of the Ste. Genevieve in Illinois and Missouri (the Fredonia oolite) was always St. Louis and in places perhaps Warsaw or Spergen limestone to him.

*Worthen, A. H. Report on Hardin County. Geology of Illinois, Vol 1, p. 356, 1866.

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But, as might be expected, Worthen's indiscriminating reliance on fossil evidence sometimes led him to inconsistent conclusions. Thus, on the two recorded occasions when he studied the section in Monte Sana, near Huntsville, Ala., where the 200-foot mass of limestone that corresponds to the stratigraphic interval represented in western Kentucky by the Ste. Genevieve limestone, Aux Vases sandstone, and Gasper oolite and which contains many fossils in which the obviously Chester element is distinctly predominant over the older St. Louis reminders, he did not hesitate to place the whole of the Ste. Genevieve, as there developed, into his Chester group. And Hall,* doubtless at the instance of Worthen, speaks of a thin bed (4 ft.) of decomposing chert—now known to represent the unconformable weathered top of the underlying St. Louis limestone—as holding "the place of the ('Ferruginous' Aux Vases) sandstone." The overlying 200 feet of limestone they correlated with the mass of limestone—now known as the Okaw limestone—shown at the base of the bluff at Chester, Ill., and to better advantage to the north of that city. This correlation, of course, is erroneous, as also are the relations assigned to the overlying Chester beds in the two sections (Chester, Ill., and Huntsville, Ala.), but it implies clearly enough that neither Worthen nor Hall felt any doubt as to the Chester age of the Mississippian beds in Monte Sana down to at least the top of the "decomposing cherty layers."

Worthen's Monte Sana section was reprinted by Safford in 1869.† "It appears here with some changes, having been revised recently by Mr. Worthen." Considered from present viewpoints, the changes are not very important. Aside from the reference of the beds above the "decomposing cherty layers" to the Chester group (instead of Kaskaskia limestone) and the elimination of the cherty layers themselves, they affect only the names of some of the fossils. The really important fact is that the Chester group of Worthen still conforms to the original intention of including all the beds down to the top of the St. Louis. In other words, the whole

*Hall, James, Iowa Geol. Survey, Vol. 1, pt. 1, p. 115, 1858.
†Safford, J. M., Geology of Tennessee, p. 358, 1869.

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of the Ste. Genevieve, including the horizon that previously and since has furnished thousands of specimens of *Platycrinus huntsvillae* to collectors in the vicinity of Huntsville, is referred on this occasion by Worthen, as it had been previously by Worthen and Hall, to the series of beds or formations for which Worthen proposed the term Chester group.

As is well known, Safford, in his Geology of Tennessee, generally used the term "Mountain limestone" instead of either of the American terms Chester group, which is exactly synonymous, or Kaskaskia limestone, which would not have been strictly appropriate because the original definition of the Kaskaskia limits it below by the top of the Aux Vases ("Ferruginous") sandstone. Besides, the delineation of this boundary in Tennessee at that time would have been practically impossible, because it falls in the midst of a mass of limestone (the Monte Sana limestone of Ulrich, 1911) whose separation into its Ste. Genevieve and Gasper components seems even today as an impracticable undertaking. Here and there in the Allegheny plateau region satisfactory results might be attained but in many other places the task would be so difficult and the result so uncertain that the effort is not to be recommended at present.

However, the discussion of this matter may be deferred with advantage to later pages. Here I wish merely to emphasize the fact that Safford, under the name Mountain limestone instead of Chester group, associated under a single stratigraphic term all the beds that in Tennessee and Alabama lie between the top of the cherty *Lithostrotion canadense* bearing St. Louis limestone and the base of the Pennsylvanian. In each of the four sections published by Safford the presence of the Ste. Genevieve at the base of the "Mountain limestone" is clearly indicated. Over the Ste. Genevieve, with its upper limit generally doubtful, is the unquestionable representative of the Gasper oolite of Kentucky; and over this a rather thin but very persistent sandstone. On the north this sandstone passes into the Cypress sandstone of Mr. Butts's section, on the south into a sandstone shown in the Monte Sana section that

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we believe to be the same as the Hartselle sandstone in northeastern Alabama.

The foregoing data and logical inferences constitute the historical part of the evidence on which I have referred the whole of the Ste. Genevieve limestone to the Chester group. To me this evidence seems absolutely conclusive, and especially so when it is found to be in complete harmony with the testimony of the beds themselves and their fossils.

CORRELATIONS BY FOSSILS AND OTHER CRITERIA.

MODERN REQUIREMENTS IN CORRELATING BY FOSSIL FAUNAS.—The mistaken assignment of the cherty top bed of the Ohara to the Cypress sandstone in 1905—an error acknowledged on a preceding page—is only one of many instances wherein blind reliance on what we thought we knew respecting the vertical range of fossil marine types has led us astray. The fossils collected from the misplaced limestone were so decidedly Chesterian in aspect that under conceptions then prevailing regarding their stratigraphic range, the propriety of assigning the bed containing them to a supra-Ohara position in the geologic scale seemed unquestionable.

Such cases should teach us to be very cautious in correlating beds on the unsupported evidence of merely generalized faunal similarity. Besides, paleontologic experience has reached that stage when it is no longer necessary to prove that the first appearance of a generic or broadly conceived specific type in a standardized geologic column most probably does not imply its inception in nature. As a rule it means no more than the first of the known invasions of some particular marine basin by a particular type of animal. Moreover, subsequent unbiased investigation is ever likely to show that the same type had invaded the same general area on one or more preceding occasions.

In correlating we should endeavor to recognize these particular invasions; but that is impossible on the basis of generic similarity of fossil contents. It is possible only on the basis of identification of minutely discriminated organic mutations. When it comes to the

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actual time ranges of more broadly conceived systematic units, as for instance the various mutations of the structural types which paleontologists commonly have referred to collectively as *Talarocrinus ovatus, Talarocrinus sexlobatus, Mesoblatus glaber, Diaphragmus elegans,* etc., our information can never be final. New discoveries tend continually to increase the accredited ranges of the "species," and their value as horizon markers necessarily becomes correspondingly less definite. The only practical way to counteract this tendency and at the same time to achieve the greater accuracy of stratigraphic reference now being demanded is by differentiating the fossils into closer and closer systematic units.

Regarding *Talarocrinus ovatus,* I have specimens that might be loosely referred to this species, (1) from the shaly bed of the upper Ohara, (2) from the top limestone of the Ohara, (3) from the lower limestone of the Gasper (the new name of the Tribune limestone of Caldwell County), and, (4) from the upper limestone of the Gasper. Moreover, a similar form occurs even as low as 20 feet or more beneath the top of the Fredonia. Critically compared, however, all of these occurrences are distinguishable by peculiarities in the structure of the calyx and vault; and only one of them—in Kentucky it has been found only in the Gasper—seems indistinguishable from typical examples of *T. ovatus* in the Springer collection at the United States National Museum that were taken from Renault exposures in Monroe County, Ill., where Worthen collected the specimens on which he founded the species.

Possibly some would prefer to class certain of these forms as varieties of *Talarocrinus sexlobatus* rather than *Talarocrinus ovatus.* I think, indeed, that such a view would be right, having myself on occasions listed them as *Talarocrinus cf. sexlobatus.* Thus, referring to a label written in 1890 for specimens found in the lower part of the Ohara, I wrote "*Talarocrinus* (near *sexlobatus*)." Specimens more definitely referred to *sexlobatus* in 1890 came from the upper limestone of the Gasper and from the shale bed that separates the upper and lower limestones of that formation.

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Though *Talarocrinus sexlobatus* is credited in current literature to the St. Louis limestone, investigation of Shumard's original type of the species, now in the Springer collection, indicates with reasonable certainty that it came from the Gasper oolite. It appears, further, that most of the Gasper specimens tentatively referred to *T. sexlobatus* are in fact more properly referable to Lyon and Casseday's species *T. symmetricus*. Beside these four or five other species of *Talarocrinus* have been described from the Gasper oolite in Kentucky, namely, *T. ovatus* Worthen, *T. patei* Miller and Gurley, *T. decornis* Wachsmuth and Springer, *T. subglobosus* Wachsmuth and Springer, *T. elegans*, Lyon, and probably *T. cornigerus* Shumard; and I have taken advantage of the present opportunity to publish illustrations of three or four additional species from the same formation. Evidently the Gasper oolite and its equivalents in Illinois—the Renault and Paint Creek formations from which I know three species—is the most prolific horizon for this genus of crinoids.

Regarding *Mesoblastus*, specimens that may in a general way be referred to as *M. glaber* occur not only in the shaly bed of the upper Ohara, from which the species was originally described, but also in the Fredonia 8 or 10 feet beneath the Rosiclare sandstone. Mr. Butts found one last August in the Cedar Bluff quarry at this horizon; and if I am right in determining the whole face of the Ste. Genevieve limestone quarry at Hopkinsville as Fredonia, the same zone yielded another specimen two days later. Evidently, then, a form of *Mesoblastus glaber* is not especially rare in the Fredonia member. Besides, it is not at all certain that these Ste. Genevieve blastoids are clearly distinguishable from the St. Louis limestone specimen that Shumard had previously described under the name *Pentremites kirkwoodi*. But this specific type ranges not only far beneath the upper Ohara, to which some paleontologists have thought it confined or restricted, but also far above, for it appears again at localities in Kentucky and Tennessee in the upper limestone of the Gasper in so slightly modified a form that I have not yet discovered peculiarities that will effectually distinguish it from the Ohara

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specimens. The same, or a very similar variety, has been found also in the Paint Creek formation in Illinois, and in apparently contemporaneous beds in east Tennessee.

Finally, what reasons warranted the until very recently prevailing assumption that the well-known Chester brachiopod, *Diaphragmus elegans*, began its existence at a geological moment marked in the Cedar Bluff section by the bed lying 6 feet above the top of the brecciated layer that Prof. Weller regards as marking the beginning of the Chester series at this place? What about the derivation of this particular generic and specific type of productoid shells? Which forms are its ancestors; and where shall we look for them? Obviously, these must have existed somewhere before the time of the mentioned upper Ohara invasion of the western Kentucky area.

Collections made by me many years ago, now partly preserved in the United States National Museum, prove that a species of this genus did exist in the same area during the deposition of not only the upper Ohara and succeeding Chester ages, but also during the time of the Fredonia.* But even the Fredonia examples had already acquired the essential features of the lower Chester or Monte Sana developmental stage of *Diaphragmus elegans*. In fact they are practically indistinguishable from one or two mutations that are found so abundantly in the upper Ohara. Certainly these two lower and upper Ste. Genevieve occurrences of the species are more nearly the same than is either like the succeeding upper Gasper mutation. The latter commonly has somewhat coarser ribs than have its progenitors. And yet all of these Monte Sana occurrences of *Diaghragmus* are more closely related to each other than they are to the succeeding typical form of the species *elegans* which is characteristic of the Birdsville faunas.

These points are discussed here only to show the general incompetence, or at least inconclusiveness, of arguments favoring correlations based on incomplete

*Evidently this species is to be found also in the Ste. Genevieve limestone in the Mississippi Valley, it having been reported from there by Shumard so long ago as 1859. (See St. Louis Acad. Sci. Trans., Vol. 1, p. 406.)

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data respecting the introduction of certain "species" or genera or on loosely made identifications of species of *Talarocrinus, Mesoblastus, Diaphragmus,* or any other kind of fossils. Before such arguments may be accepted as valid, not to say incontrovertible, it should be clear that the author has exhausted all means of arriving at a satisfactory conclusion—among them in this case, that he has critically studied not only the upper Ohara fossils of the Kentucky region but similarly complete collections from the underlying Fredonia and the overlying members of the Gasper oolite in the same region. We must feel assured, further, that his collections have been made with due regard to the stratigraphy. Also that he has studied at least certain classes of his material sufficiently to be able to discriminate and recognize the minutely indicated mutations that distinguish the correspondingly minor stages in the evolutional history of all complexly organized animals. From the standpoint of stratigraphic correlation it is absolutely necessary to discriminate these biologically perhaps unimportant mutations, because they afford the only inherently competent means of exactly correlating stratigraphic horizons and geological dates.

In accord with this principle the stratigraphic or correlation value of a fossil is in direct proportion to its relative complexity of structure. If the features for comparison are many and definitely determinable, the indexical value of the fossil is correspondingly great; if the structure is simple and comparable features limited in number and not readily determinable, the usefulness of the fossil in stratigraphic correlation is correspondingly inferior.

No class of invertebrate fossils found in the Chester formations in the Mississippi, Ohio, and Appalachian valleys is more complex in structure or more generally distributed and abundant than the *Pentremites*. They seem, therefore, admirably adapted to test the truth and practical applicability of the principle of minute discrimination in stratigraphic correlation. Besides, very excellent collections, aggregating a total of more than 20,000 specimens, were available for study in the collections of the United States National Museum. These

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were gathered at more than 100 Chester localities in Illinois, Missouri, Kentucky, Indiana, Ohio, Virginia, Tennessee, Georgia, and Alabama. Of great advantage, too, is the fact that these collections include the original types of all the previously described valid Chester species of the genus except those of *P. godoni, P. Pyriformis, P. sulcatus, P. symmetricus*, and *P. cherokeus*, of which species the types could not be located.

Accordingly, the past three months were devoted to an intensive study of this material. Over 100 "species," "varieties," and "mutations" have been discriminated; and a large majority of these has been identified in widely separated localities. Indeed, the biologic results of this study and their bearing on questions of correlation have fully repaid the time and labor devoted to it.

EARLY INVESTIGATIONS OF THE FAUNAS OF THE STE. GENEVIEVE AND GASPER LIMESTONES.—Large collections of fossils from the lower (Fredonia oolite) and upper (Ohara limestone) members of the Ste. Genevieve limestone were made by me in western Kentucky during the field seasons of 1888, 1889, and 1890. These were studied during the intervening and succeeding winters and the results carefully listed. Unfortunately, neither the fossils nor the lists of these early collections were available when the manuscript for Professional Paper 36, published by the U. S. Geological Survey in 1905, was being prepared. However, these deficiences are now in hand. The old lists show not only that the determination of the fossils was carried out with great care and with unusual attention to minor details of structure, but also with, what was then, uncommon regard to their zonal and areal distribution. The lithologic changes in the sections also were noted in considerable detail, the typical outcrop of the Ohara member of the Ste. Genevieve, for instance, being divided into 10 beds. The Rosiclare sandstone, seldom over 2 to 3 feet thick in western Kentucky, was early recognized as a valuable datum plane. The conglomeratic or brecciated bed which lies about 23 feet above the Rosiclare sandstone in the Cedar Bluff section, and which Prof. Weller interprets as marking the unconformable base of the Ches-

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ter at this place, also was observed in 1888 and commented on in notes of that date now before me.

The fossils, as stated, were collected and listed as closely as possible according to more or less limited zones. Thus, a list comprising a total of some 30 species was prepared of fossils found in the first 15 feet beneath the Rosiclare sandstone. Another list was made of those found in the widely distributed coral zone (*Lithostrotion harmodites, Cystelasma quinqueseptatum,* and *Michelinia subramosa*) which makes up the next underlying 24 feet. And a third list gave the species found in the more or less cherty zone, about 20 feet thick, which underlies the coral bed. The last seems to be the lowest of the Ste. Genevieve beds with a large and varied fauna, the fossils being apparently both less common and less varied in the lower beds of the formation. Composite lists of the three upper zones of the Fredonia gave totals of 68 species at one locality in Crittenden County, and 61 species from a single exposure near Princeton in Caldwell County. As will appear later, the total known fauna of the Fredonia in western Kentucky exceeds 140 species.

In a similar manner the species of the Ohara member of the Ste. Genevieve and of the succeeding fossiliferous Chester zones were discriminated and listed. But, as little or practically no difference of opinion now prevails respecting the correlation of the beds above the base of the typical Cypress sandstone, that is, above the base of the Birdsville formation or, more properly, group, it seems unnecessary to present a review of the work required to bring our information regarding the formations of the Birdsville group to the stage attained at the time of the publication of Professional Paper 36. But no such harmony of views is evident with respect to the formations beneath the Birdsville. On the contrary, much difference of opinion still obtains regarding the respective ages and correlates in Illinois and elsewhere of the Ohara member of the Ste. Genevieve, of the overlying Aux Vases sandstone (the "Cypress" of Prof. Paper 36), and of the "Tribune" or Gasper oolite, as it is now to be called.

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Concerning these, therefore, it seems desirable to present at least a partial statement of the labor required to build up the evidence on which the classification published by me in 1905 is based.

In 1888-1890, when most of the work on the Ohara limestone and Gasper oolite was done, the exposures of the Ohara on the nearly bare southern slope of Cedar Hill, two miles east of Princeton, were in much more favorable condition for collecting fossils than they are at present in the fresh cuttings of the large quarry now in operation at this place. In fact it would be almost impossible now to gather the fauna of 42 species then procured from the 40 feet of shelly-weathering limestone lying between the brecciated bed and the overlying soft shale bed which contains a somewhat different association. The fauna of this higher shaly zone is not so profusely developed here as in Crittenden County where the listed species from this bed at a single locality reached the respectable number of 45.

For some reason, at present inexplicable, the peculiar and pre-eminently Chesterian fauna of the 16 feet of rather heavily bedded cherty limestone at the top of the Ohara section in Cedar Hill, where the sequence of beds and faunas of the upper half of the Ste. Genevieve limestone was mainly worked out, was barely observed by me prior to 1916. This oversight proved unfortunate because, as already mentioned, it led to, or at least permitted, a misconception regarding the overlying Aux Vases sandstone. Had I known of this topmost fauna of the Ohara, I should most certainly not have been misled by apparent topographic relations of nearby outcrops of sandstone at Shetlerville, Ill., to the erroneous conclusion that a limestone exposed between them—cherty and with precisely this then unrecognized topmost Ohara fauna—represents a locally developed calcareous median member of the Aux Vases sandstone. With a knowledge of this fauna, the true explanation of the disposition of the concerned beds—that is, a repetition of the sandstone because of faulting—must at once have suggested itself.

The faunas of the Gasper oolite were first observed and collected by me in Lambs Cut, on the Illinois Central Railroad, about 6 miles east of Princeton. Because of

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the then unheard-of association of Spergen and Chester species, this locality excited unusual interest and, therefore, was visited repeatedly during the years 1888 to 1890. Besides, at that time the bedded rocks and residual clays through which the cut had been made were in excellent condition for collecting their faunas.

Three distinct beds, dipping toward the east, were exposed in the cut—a bed of calcareous shale in the middle, with oolitic and subcrystalline crinoidal limestone to either side. The crinoidal limestone was the lowest of the three. The liberated fossils of the limestones were all silicified, and washed by rains out of the residual clays lying on and between boulders or remnants of the decomposing limestone ledges.

As this was my first clearly recognizable case of recurrent faunas, the collections were most carefully and fully made, those from the two limestones being kept separate from each other and from those taken out of the shale.

As determined and listed in 1889 or 1890—according to the original lists now before me—the lower limestone afforded 14 species, all but three of them crinoids and blastoids of decidedly Chester aspect. The three exceptions: *Productus inflatus, Cliothyridina sublamellosa* and *Composita trinuclea var.* were very abundant. The fauna of the shale bed, numbering more than 40 species, also comprised only typical Chester species.

The collection from the upper limestone, however, included a large and, at that time, most disconcerting proportion of specific types theretofore observed only in the Spergen. In fact nearly half of the total of 80 species collected from this bed in Lambs Cut consisted of these Spergen reminders and the other half was largely made up of species of uncertain stratigraphic significance. Except for the presence of seven clearly Chester species of *Archimedes*, I might have succumbed to the temptation of drawing a fault between the shale and upper limestone, and referred the latter to the Ste. Genevieve or even to the Spergen limestone.

Presently, however, incontrovertible stratigraphic evidence was procured a few miles to the southeast from Lambs Cut in the area adjacent to the boundary between

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Caldwell and Christian counties, showing conclusively that this limestone with the recurrent Spergen fauna lies above the other two beds shown in Lambs Cut, and that all three overlie the Aux Vases sandstone (Cypress sandstone, Ulrich 1905). The unbroken sequence in this area established, further, that the upper limestone is succeeded by the sandstone subsequently described by me as Bed 1 of the Birdsville formation and now known to correspond to the typical Cypress of Johnson County, Ill. All reasonable doubt as to the actuality of the formation subsequently described by me under the unfortunately selected name "Tribune limestone" was thus overcome before the close of the year 1889.

Through these extensions of the study of the Gasper ("Tribune") oolite, the faunas, particularly that of the upper limestone member, were considerably increased. The Spergen element maintained an at least even pace with the total increase. All told, the Gasper fauna as represented by these old collections comprises about 170 species. Of this number 28 were found in the lower limestone, 68 in the shale member, and 120 in the upper limestone.

I venture to say that the fauna of no other formation of the Chester series has, up to the present, received closer scrutiny than was bestowed by me in those early days on the Gasper fauna. As the fossils of the underlying and overlying Mississippian—particularly Tennessean—formations of the same general region were then subjected to similarly detailed investigation, I submit that the chances of error in the determination of the sequence and correlation of the formations and their members—in so far as this is possible on the basis of fossil evidence—had been reduced, when Professional Paper 36 was published, to a degree not surpassed by the work of others to date.

Confirmation of foregoing statements respecting the paleontologic work accomplished up to 1890 may be found in the U. S. National Museum, where the fossils and most of the original labels are now preserved and available to those interested.

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DIFFICULTIES IN THE WAY OF CORRELATING BY OTHER MEANS THAN MATCHING OF MINUTELY DISCRIMINATED FOSSIL REMAINS.—The long-prevailing belief in continuous deposition in broadly extended continental seas, with the consequent assumption that regional differences in lithologic character and organic contents of beds holding apparently similar positions in the stratigraphic sequence at different places indicate only local variations in contemporaneous deposits and faunas, has operated perhaps no less potently than loose identification of fossils in delaying the progress of refined and exact correlation of geologic events and formations. The possibility that some of the sandstones intercalated at intervals in series of prevailingly marine deposits might be of continental origin—hence that the seas at such times were withdrawn, or that the surface of the continent was and is subject to frequently recurring and locally varying (differential) vertical oscillations which occasion corresponding advances and retreats of the strandline, or that the geographic pattern in the successive stages varied not only in aggregate extent of either sea or land areas but also very greatly in the relative effects of the submergent stages on particular areas was barely considered. Recognized unconformities were few and contemplated only as occurring in certain regions between some of the systems. That great stratigraphic hiatuses, due more to nondeposition on lowly emerged areas than to removal of missing beds by erosion, are really of common occurrence was scarcely conceived. That such breaks in the sedimentary record occurred very often, and that resubmergence might commonly take place without leaving a basal conglomerate to mark the advance of the new sea must have seemed inconceivable. But all of these newer conceptions have been incorporated in the science as now taught.

Examples of the application of the old conceptions in geologic investigations of formations included in the scope of the present studies are numerous. Thus Hall* and, presumably, also Worthen, who made the investigations in Alabama reported by Hall, correlated a thin bed of very cherty material in the section of Monte Sana

*Hall, James. Geology of Iowa, Vol. 1, pt. 1, p. 114, 1858.

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with the Aux Vases ("Ferruginous") sandstone of the Mississippi Valley. About the same time Lyon† published a classification of the rocks of Kentucky beginning with the Silurian and ending above with the base of the "Coal Measures." The deposits of the Chester group he described under the term "Millstone Grit Series." His conclusions regarding the base of the Chester are of interest here because he regarded this group as overlapping on what he called the "Cavernous limestone." His "First sandstone of the Millstone Grit series," which in Breckinridge County is the bed to which Mr. Butts now applies the new name Sample sandstone, he believed to lap out southwardly and with it the "first limestone" (upper member of the Gasper), so that in Edmonson County his "Second sandstone" (more recently known as the Big Clifty and now as the Cypress sandstone) came to rest on the "Cavernous limestone" which he excluded from the group. In fact, however, no such overlap occurs in any part of the area with which he was familiar. In that area only the Sample sandstone pinches out, the upper and lower members of the Gasper oolite then being in contact.

Because of this and related misapprehensions Lyon's identification of the beds of the lower and middle parts of the Chester series in Kentucky was not consistently determined. In his practice the first sandstone in the section above the St. Louis limestone always marked the beginning of the Chester. Accordingly, in Crittenden County, where the Sample sandstone is not developed whereas two older beds of sandstone—the Rosiclare and the Aux Vases—do occur beneath its position and yet above the St. Louis, he correlated the Ohara member of the Ste. Genevieve with the "First limestone" (upper Gasper) of his Breckinridge County section. Starting with this error, he naturally fell into others in dealing with overlying beds. Thus, for instance, he referred at least one outcrop of upper Gasper limestone to his "Third limestone." In Breckinridge County, however, the equivalent bed is his First limestone, and the Glen Dean his Third limestone.

For similar reasons, or perhaps merely following

†Lyon, S. S. Trans. St. Louis Acad Sci., Vol. 1, p. 612, 1857.

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Lyon's lead, Wachsmuth, Wetherby, and others who collected the crinoids and blastoids and incidentally studied the rocks containing them in Tennessee and Alabama, credited their Gasper and Ste. Genevieve species to the St. Louis limestone. Even Worthen was influenced by these erroneous opinions, the new crinoids collected by him from the Monte Sana limestone near Huntsville, Ala., and later described in 1892, being doubtfully referred to the St. Louis limestone.

I have no intent to belittle the work of these pioneers in American geology. On the contrary I learned to esteem the mentioned geologists as keen observers and excellent paleontologists. And I feel sure that their mistakes in Kentucky and Alabama stratigraphy are ascribable to misconceptions generally prevailing in their day rather than to their own faulty observations. Had they disregarded the idea of a supposedly essential basal sandstone and paid more attention to the discrimination, sequence, and correlation of peculiar associations of fossils, most of the mentioned errors would have been avoided.

When I began my work on the Mississippian rocks of western Kentucky the same old ideas were yet dominant. Even after I had been forced to the conviction that the Spergen fauna persisted to well into the Chester age, I fell into the error of supposing that the upper Gasper occurrence must be the last. Therefore, when I found an oolitic limestone with such a fauna in the basal part of the section near Chester, Ill., it was assumed without question that the containing rock is of the same age as the Gasper limestone in which it was found in western Kentucky, and the false inferences based on this assumption were expressed with considerable confidence in Professional Paper 36. But this identification was in error, for, as we know very well now, the oolite at the base of the bluff below Chester is not in the Gasper, or "Tribune" limestone as it was then called, but a similarly oolitic bed in the Okaw limestone. In other words, it belongs in the lower part of the Birdsville group and not, as I thought, in the upper part of the Monte Sana group.

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STRUCTURAL DIFFICULTIES RETARDING CORRELATION OF ILLINOIS AND KENTUCKY FORMATIONS.—Difficulties are unavoidable—and in the end probably some uncertainties must remain—in trying to fit the details of the Randolph County, Ill., section to my classification of the more continuously exposed and more clearly punctuated sequence of Chester beds in western Kentucky. And these both real and apparent inconsistencies would seem to be particularly inexplicable to those who have begun their investigation of the series in Randolph and Monroe counties. But it is not the Ohio that draws the geographic boundary between these two differently constituted sequences of Chester deposits. On the contrary, the Chester formations in the southernmost tier of counties in Illinois, comprising Union, Johnson, Pope, and Hardin counties, are practically the same in sequence and character as those found encircling the western Kentucky coal field. The area in which the change actually occurs lies entirely in Illinois, that is, in the little-known stretch of 50 miles or so that separates the well-determined sections in Randolph County from those in Union County. Something happened in this intervening area which is not clearly understood at present.

The imperfect data respecting the Chester in Jackson County, which occupies the greater part of this intervening area, suggests some kind of barrier crossing it from southeastern Missouri in a northeasterly direction. This barrier probably coincides in position with an old anticlinal axis that at various preceding times in the Paleozoic history of this region limited or otherwise affected the distribution of marine sediments.* At any rate, fairly satisfactory evidence is in hand showing

*Northeastwardly dipping rocks in the southern part of Jackson County, Ill., indicate complications because of intersection or other connections with geologic structure observed in Ste. Genevieve County, Mo., where at intervals, from the Cambrian on, a northwestwardly trending depression received marine deposits that seem not to have been laid down to either side of it. Whatever the relations of the intersection axes, their supposed effect on the distribution and character of the Chester seas and sediments would seem but repetitions of conditions and processes that obtained previously in the Oriskany age and caused deposition of limestone in Ste. Genevieve County and sands or other highly siliceous rocks in Union County, Ill., and adjacent areas to the south. More or less convincing evidence showing various likely effects of such a barrier in this place is in hand concerning several Ordovician, Silurian, Middle Devonian, and Mississippian formations. Something of the kind surely affected these older formations, and it seems therefore reasonable to expect similar phenomena in the Chester deposits.

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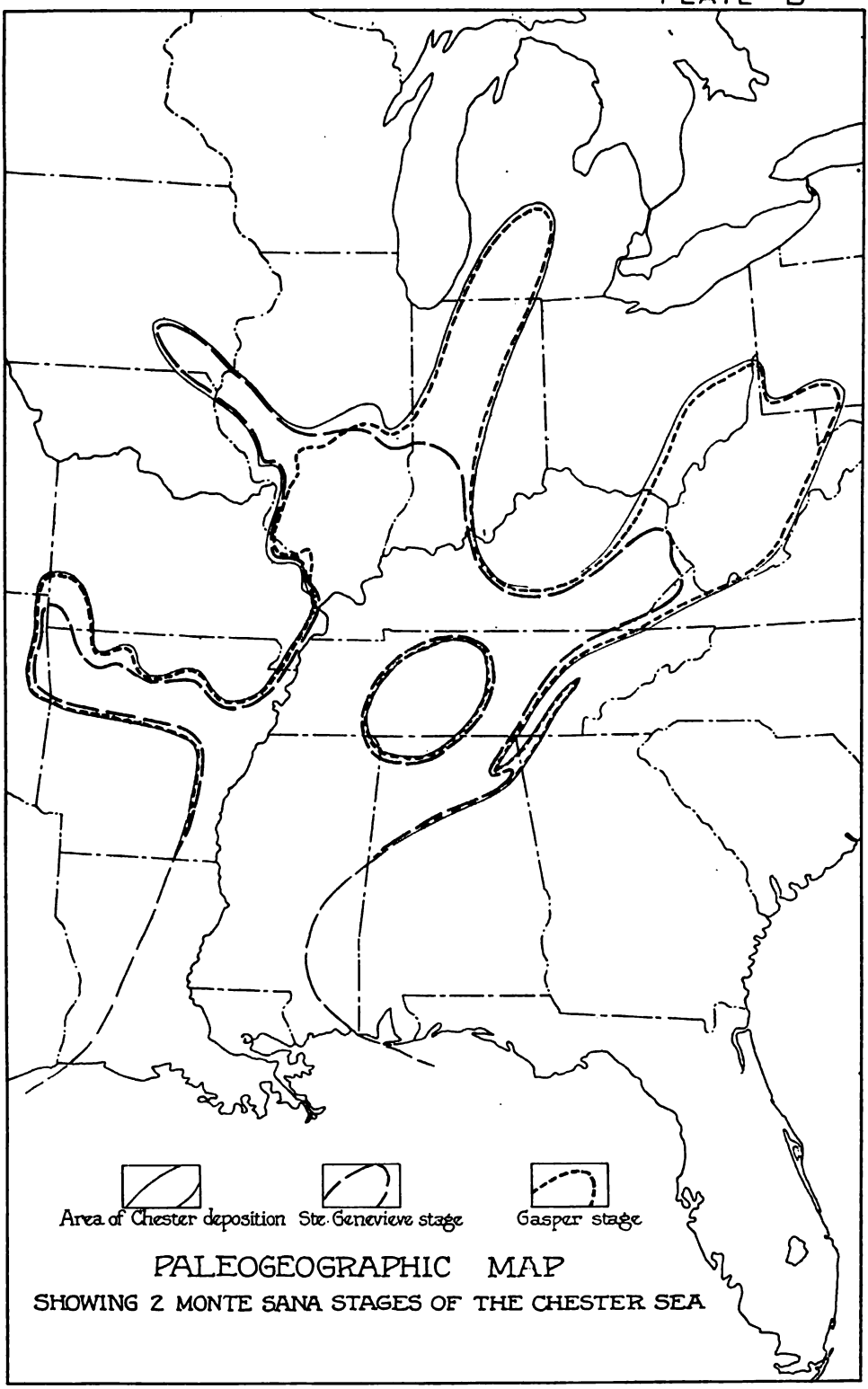
PLATE B



PALEOGEOGRAPHIC MAP

SHOWING 2 MONTE SANA STAGES OF THE CHESTER SEA

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that the Chester in this area is thinner than it is to either side of the supposed barrier. Certain beds apparently lap out on its limbs. If the presence of such a barrier were established the difficulties that now embarrass us in seeking to correlate the Chester formations beneath the horizon of the Glen Dean which, like the succeeding formations of the series, spreads in typical or at least easily recognizable form across both areas, might be readily explained and perhaps overcome.

Comparative study of Chester lithology shows that to the northwest of the supposed barrier the deposits of the Chester, except the Aux Vases sandstone in the lower part and the Palestine sandstone in the upper, consist almost entirely of limestones and calcareous shale. To the southeast, on the contrary, sandstones and finer clastics predominate in decreasing ratio to south central Kentucky. Passing across the State boundary into Tennessee the Cypress is the only sandstone remaining, the remainder of the series, from the top of the underlying St. Louis limestone to the base of the Pennsylvanian, being made up of limestone and more or less calcareous shale. The Cypress persists thence as an important datum plane marking the base of the Birdsville group to northeastern Alabama. Most of the Chester sandstones seem to be flood-plain or possibly beach deposits.

Speculations regarding the physical conditions that were responsible for these peculiarities in the areal distribution of the Chester sandstones suggest that Randolph County during certain times of this epoch was included in an embayment of the Chester sea to which much less of land detritus was carried by streams than more actively eroding streams poured into the main body of the continental sea which lay to the southeast and extended thence to the southern Appalachian region. On the north it made a broad embayment covering the area between central Illinois and central Indiana and also, to the east of the Cincinnati axis which doubtless formed a long peninsula, two or three other embayments which at times stretched into southeastern Ohio and southwestern Pennsylvania.

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Except the Cypress sandstone, which also becomes much thinner to the southwest from Illinois, there is no sandstone worth mentioning in at least the lower two-thirds of the Chester series as developed in eastern and southern Kentucky, east of Todd County and in Tennessee, and northern Alabama. This southeasterly diminution in the proportionate volume of the clastic part of the sediments leads to the inference that the lands which supplied this material lay to the west, and the stream or streams that transported it either emptied directly into the sea at some place near the city of Cairo or distributed their burden of eroded material on a coastal plain.

Considerations like the foregoing lead to the reasonable suggestion that conditions favoring the existence of marine life and the deposition of fossiliferous limestone may have prevailed at times on one side of the supposed barrier and not on the other. For instance, the approximately lower three-fourths of the Okaw limestone of the Randolph County area, which finds no satisfactory faunal or lithologic parallel in western Kentucky, may have been deposited during the time represented to the south by the Cypress sandstone. The only objection to this hypothesis that occurs to me now is the fact that the area of Cypress sandstone, which must have been laid down in very shallow water, lies between the Randolph County basin and the inlet from the Gulf of Mexico through which the fauna of the Okaw as well as all other stages of Chester marine life in the Mississippian province must have passed. But this difficulty is not necessarily fatal because it is readily conceivable that even if the invading marine fauna found itself unable to maintain existence on the sandy Cypress beach and bottom, the unattached larvæ of its species may yet have been carried over the intervening unfavorable area to the farther basin in which they could attain maturity and insure propagation.

The dominant varieties of *Pentremites* found in the Okaw limestone, especially the typical form of *Pentremites sulcatus*, have not been observed in the Chester formations in Kentucky. I infer, therefore, that this limestone is not represented in Kentucky by deposits

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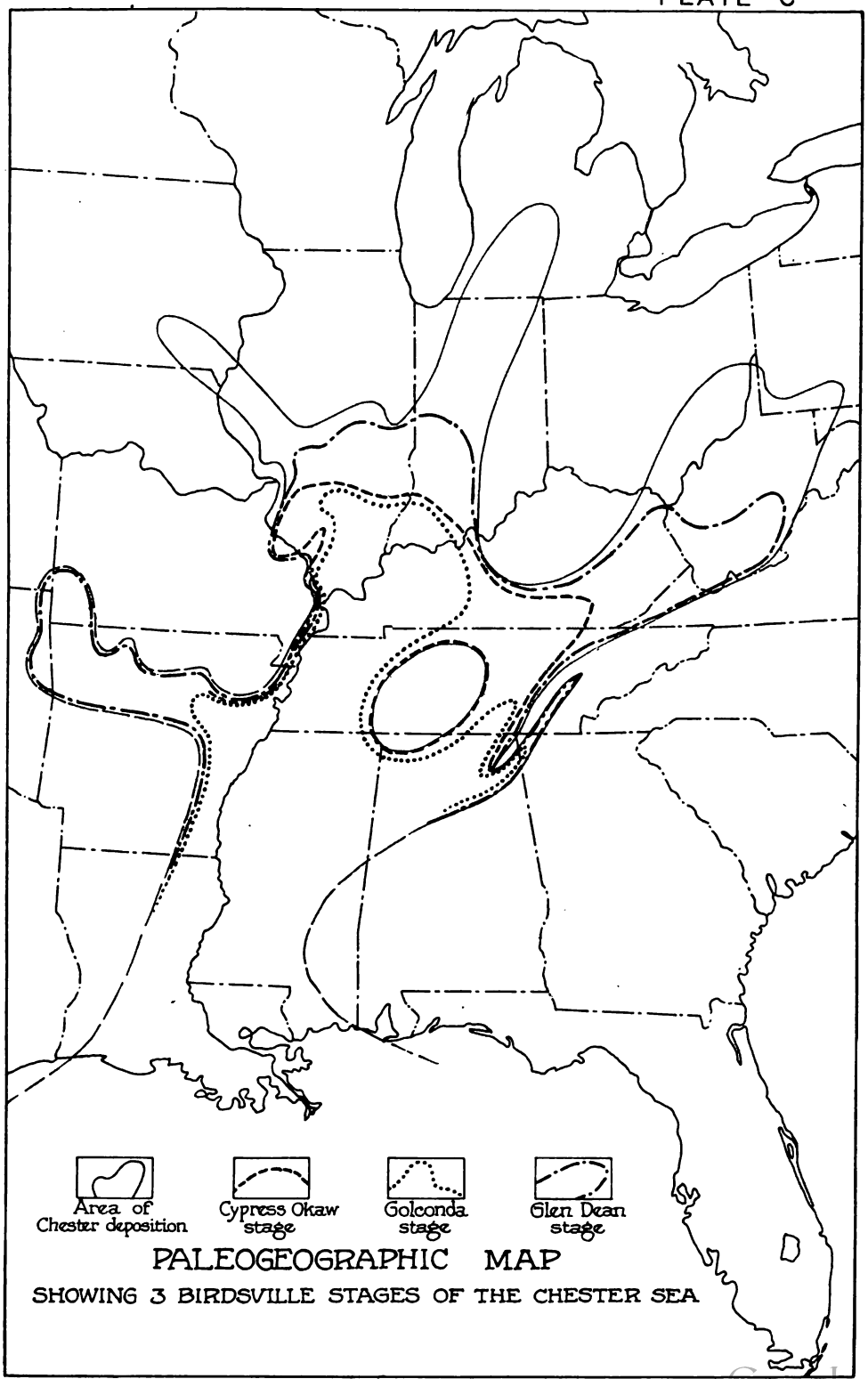
PLATE C



PALEOGEOGRAPHIC MAP

SHOWING 3 BIRDSVILLE STAGES OF THE CHESTER SEA

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similarly favorable to the existence and preservation of marine faunal remains. As the Golconda formation in the latter area contains its own characteristically distinct fauna, it seems highly improbable that it was laid down at the same time as the lower or some middle part of the Okaw. No reason is apparent, assuming their contemporaneity, that might have prevented free interchange of their respective faunas. That the most characteristic fossils of the Okaw limestone have not been recognized in the Chester formations to the south of Jackson County, Ill., and those of the Golconda have not been seen in the Randolph County area is well known to modern investigators. The delay in finding a satisfactory explanation of this faunal discord has occasioned perhaps the most troublesome of the difficulties hitherto encountered in correlating the formations in the two regions.

Circumstantial evidence that we are warranted in accepting as corroborative of the positive and negative testimony presented by the two formations themselves is contributed, first, by the Paint Creek formation which, with its sandy closing stage—the Ruma, directly underlies the Okaw limestone, and second, by the shaly calcareous "Plum Creek" bed at the top of the Okaw. The fauna of the Paint Creek formation, as will be shown later on, is exceedingly like that found in the middle and upper parts of the Gasper oolite in Kentucky and Tennessee. Lithologically, also, they harmonize so well that I see no valid reason to doubt their contemporaneity. Similarly there can be no question of the Glen Dean age of the "Plum Creek" beds. In both instances the faunal agreement is surprisingly great. If we compare these positive concurrences in the faunas of the beds that overlie and underlie the undetermined interval in the two areas with the faunal discordance noted in studying the fossils of the Okaw and Golconda formations which comprise the fossiliferous parts of the interval, the contrast is sufficiently striking and important to convince me of the distinctness of the two formations. At the same time my belief in the essential contemporaneity of the Okaw limestone and the Cypress sandstone is greatly strengthened.

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The Golconda formation, on the other hand, suggests emerged conditions in the Randolph County basin and increased submergence in extreme southern Illinois and western Kentucky. But, so far as I know, neither the Golconda nor the Hardinsburg sandstone which succeeds it is present in eastern Kentucky or anywhere in the Allegheny and Cumberland plateau regions north of Alabama. It appears, therefore, that the Chester sea during the Golconda stage was confined on the east by elevation of the Cincinnati axis and restricted by emergence of all the areas to the east of this axis that in one or another of preceding Chester times had been submerged. This apparent change in outline of the sea seems to have been brought about by gentle warping of the surface of the continent. This resulted in slight subsidence and increased submergence of a relatively narrow area stretching from the mouth of Mississippi River to west central Indiana an elevation sufficient to insure continued or renewed emergence of areas on either side. Resubmergence of the latter began with deposition of the Hardinsburg sandstone and attained its maximum in the Glen Dean stage.

Under this interpretation of the middle Chester sedimentary record, the faunal and stratigraphic break between the top of the Monte Sana and the base of the Birdsville group* should be greater in western Kentucky than the one in Randolph and adjoining counties in Illinois between the Paint Creek or the Ruma formation and the Okaw limestone. The Cypress sandstone being regarded as representing the age of the Okaw limestone but without marine fossils, the faunal break is greater in Kentucky than in Randolph County by just so much as continuing marine life modified during the time required to lay down the Okaw limestone. Study of the concerned Chester faunas so far as pursued tends to satisfy the requirements of the hypothesis.

*As stated on page 152, the fossiliferous thin-bedded calcareous sandstone which is described in Professional Paper 36, as a locally developed basal constituent of the Birdsville group is now regarded as more properly referable to the top of the underlying Gasper oolite. It is also believed to correspond to at least the lower part if not the whole of the Ruma formation.

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PART 2. STRATIGRAPHY OF THE CHESTER SERIES.

GENERALIZED CLASSIFICATION AND CORRELATION OF THE FORMATIONS.

COLUMNAR SECTIONS.

To facilitate understanding of the following detailed sections of Chester formations and also the stratigraphic bearing and application of the discussion of the fossil faunas of the Chester formations in western Kentucky and their relation to beds and faunas in adjacent areas to the north and southeast, it is thought advisable to insert here some generalized and classified columnar sections of the concerned rocks as developed in the several areas. A clearer idea may be gained also of the writer's present views regarding the identification and classification of the beds in Johnson, Pope, and Hardin counties, Ill., by Engelmann and Worthen in 1862-1866, and by Ulrich in western Kentucky and southern Illinois in 1905. In the time scale the larger units are as revised and published by me in 1911.* The sequence and names of the minor units are as recently adopted in conference with Prof. Stuart Weller, Mr. F. W. DeWolf, Mr. G. H. Ashley, Mr. G. H. Girty, and Mr. Charles Butts and approved by the Committee on Geologic Names and the Director of the United States Geological Survey.

LATERAL DIMINUTION AND ELIMINATION OF THE SANDSTONE BEDS.—One of the most interesting features brought out by these columnar sections is the lateral diminution and, in most instances, complete elimination

*Revision of the Paleozoic systems. Geol. Soc. America Bull., Vol. 22, 1911.

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of the sandstone beds. As shown in the sections, the Chester series as developed in the area between Johnson County, Ill., and Christian County, Ky., includes six continuous beds of sandstone (one more than Engelmann thought) with maximum thickness of 20 to 150 feet. The thinnest of these is the first or lowest (Rosiclare sandstone); the choice as to the thickest lies among the third (Cypress), the fifth (Tar Springs), and the sixth or last (Palestine sandstone), the maximum thickness of each being, so far as observed, approximately 150 feet. The Rosiclare sandstone, despite its inferior thickness, is a very persistent bed, being shown wherever its place in the section is exposed from the Mississippi Valley above St. Marys, Mo., to Hopkinsville, Ky., beyond which point it has not been observed. The second or Aux Vases sandstone has a similar distribution extending eastwardly in Kentucky to or slightly beyond the eastern border of Christian County. It is typically and fully developed in the Mississippi Valley but seems to pinch out, at least locally, in Union County, Ill.

Not counting the apparently only locally developed arenaceous beds of the Ruma formation in Monroe County, Ill., and the corresponding sandy beds sometimes found in the Ridenhower shale and in the upper part of the Gasper oolite, the third, and stratigraphically the most important, is the Cypress sandstone (Engelmann, 1862, not Ulrich, 1905). This sandstone holds its position and to a considerable extent its thickness through southern Illinois and western Kentucky, passing thence in diminishing volume through Tennessee into Alabama. Though about 100 feet in thickness in Johnson County, Ill., there is no sandstone corresponding to it in the Mississippi Valley proper. For reasons given on a previous page, it is believed to correspond in age to the Okaw limestone.

The fourth sandstone has been given the name Hardinsburg sandstone by Mr. Butts. It also is widely distributed in Kentucky, being especially prominent around the borders of the western coal field. South and west from this it is less clearly distinguishable from the underlying Golconda formation. So far as known the

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Hardinsburg is absent or represented by shale and limestone in Tennessee and Alabama. In southern Illinois, on the other hand, it is generally recognizable and seems to extend as far even as Randolph County where a thin sandstone locally underlies the shaly limestone bed that is confidently assigned to the age of the Glen Dean limestone of Kentucky. Commonly, however, in Randolph and adjoining counties, this Glen Dean representative alone separates the main mass of the Okaw limestone from the overlying Menard limestone.

In southern Illinois and western Kentucky the fifth or Tar Springs sandstone attains equal distribution with and locally greater thickness than the Hardinsburg sandstone. As a rule this bed is absent in the Mississippi Valley section. So far only a single occurrence of sandstone in this position has been observed there. This is a very limited deposit, apparently in an old stream valley, shown in the bluff at Chester, Ill. Finally, the sixth or Palestine sandstone is nearly as well developed in Randolph County, Ill., as in the counties to the southeast in the same State and in those across the Ohio in western Kentucky. In this State, however, it soon loses its identity, being unrecognizable as a distinct formation east of Caldwell County. Whether it pinches out or grades laterally into the other kinds of beds is undecided.

Of more local interest is the Sample sandstone which in Breckinridge and Meade counties ranges in thickness from 0 to 40 feet. Here it is developed in the midst of the Gasper oolite at apparently the same horizon as the thin bed of shale that in Caldwell County similarly divides this formation into an upper and a lower limestone member. The Yankeetown chert apparently holds a corresponding position in the section in Randolph and Monroe counties, Ill.

OTHER MATTERS GRAPHICALLY ILLUSTRATED.—Other important features shown by these columnar sections relate to the Gasper oolite and its equivalents to the northwest in Illinois and to the southeast in Tennessee and Alabama. On the basis of compelling fossil evidence, presented and discussed in detail in following

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chapters, the Gasper oolite is correlated with the Renault, Yankeetown, Paint Creek, and Ruma formations in Randolph and Monroe counties, Ill. Further, the Ridenhower shale which alone represents this general horizon in Crittenden and Livingston counties on the Kentucky side and in Pope and Johnson counties on the Illinois side, is correlated with the upper limestone and possibly the middle shale of the Gasper as developed in southeastern Caldwell and Christian counties. The lower limestone of the Gasper apparently pinches out entirely before reaching the border of Crittenden County. Compared with the Randolph County section the Ridenhower is correlated with part or all of the beds between the top of the Renault formation and the base of the Okaw limestone.

Further, they illustrate the inadequacy of efforts to determine the age of Chester beds in detached areas of outcrop by their position with respect to beds of sandstone—that is, prior to the determination of the age of the sandstone itself. To the east and southeast of the west Kentucky coal field, the first (Rosiclare) and second (Aux Vases) sandstones are commonly missing whereas another sandstone, referring particularly to the Sample sandstone which is not present in the Chester area to the west that provided the standard sequence of beds used in correlation, may be locally intercalated. The Sample sandstone, as stated before, has in such places been commonly determined as the first of the Chester sandstones. The only inherently capable way to "correlate" or determine the age of any of the limestones or calcareous shales of the series is by the identification of minutely discriminated characteristic fossil remains. As for the sandstones, they can not be positively identified except by their position with respect to these fossiliferous zones.

BEARING ON THE QUESTIONED BASE OF THE CHESTER SERIES.—Finally, these sections show the impracticability of drawing the base of the Chester series at any plane short of the base of the Ste. Genevieve. In the Mississippi Valley the base of the Aux Vases sandstone as a rule affords a conspicuously marked contact. But where-

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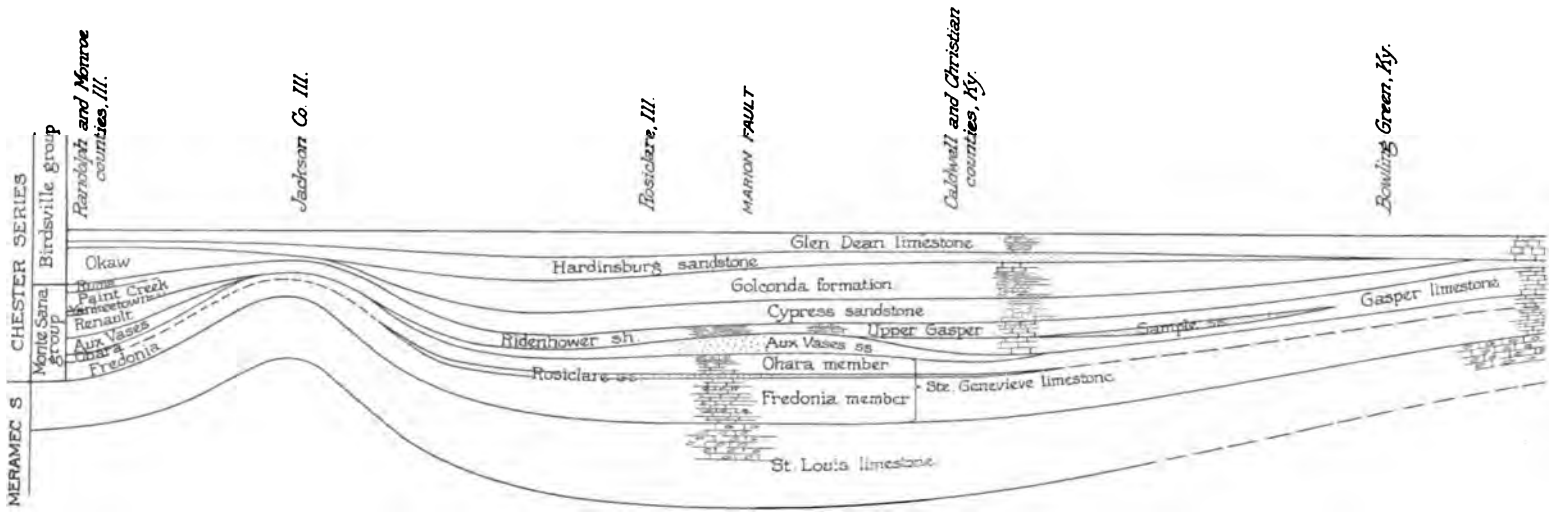
PLATE F



Cross-section between Mississippi River and Kentucky-Tennessee line, southeast of Bowling Green.

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ever fossil evidence must be relied on to point the way to the corresponding, often obscurely or unrecognizably indicated boundary, its determination is not so readily effected. There are places even in southwestern Illinois where the Aux Vases sandstone is missing and the Renault comes to rest on not so very dissimilar Ste. Genevieve deposits.

But what about the great area that includes a considerable part of southern and eastern Kentucky, the whole of the Cumberland Plateau in Tennessee and northeastern Alabama in which none of the sandstones beneath the Cypress is present and in which no one has yet succeeded in drawing a satisfactory boundary in the mass of limestone between the base of the Cypress and the top of the St. Louis? On the other hand, no one has hesitated to express his opinion definitely as to where the section passes downward from limestones of possibly more or less doubtful age to those whose St. Louis age is unquestionable. Practically everywhere the latter contain the conspicuous fossil coral commonly known as *Lithostrotion canadense*.

None of the preceding generation or two of geologists consistently placed the questioned 200 feet or so of limestone that immediately underlies the Cypress sandstone into the St. Louis or any of its synonyms. At their maximum these questioned beds correspond to the Monte Sana limestone of Ulrich—in other words, to the Ste. Genevieve limestone and the Gasper oolite. In south central Kentucky Lyon placed them in a separate division to which he applied the term "Cavernous" limestone. The beds above it he referred to the "Millstone Grit" series, those beneath it to the "Middle limestone," the upper part of which corresponds to the St. Louis limestone.

Wetherby and Wachsmuth, who recognized only two formations in the upper Mississippian, namely, Kaskaskia and St. Louis limestones, and who studied fossils rather than stratigraphy, often referred some lower part of the Monte Sana limestone to the St. Louis. However, if we may judge from the labels of fossils left by them, they had no definite views as to where the boundary between the two series would best be drawn. Collections

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from different localities but unquestionably from one and the same stratigraphic horizon were in some instances labeled "Kaskaskia," in others "St. Louis."

No such uncertainty is observable in Safford's determinations of sections in Tennessee. He invariably drew the base of his "Mountain limestone," which corresponds to the Chester series, at the first appearance of the cherty beds containing *Lithostrotion canadense*, which in his nomenclature were distinguished as the "Upper Siliceous," "Lithostrotion bed," or St. Louis limestone. In essential features Safford's practice in Tennessee was exactly harmonious with that of Worthen at Monte Sana, near Huntsville, Ala. The only difference is that Worthen used the term Chester group instead of "Mountain limestone."

As in Alabama and Tennessee, so in Pulaski and Warren counties in Kentucky the boundary between the Gasper and the Ste. Genevieve parts of the Monte Sana limestone is a purely paleontological one. In going downward in the section it is drawn at the first detection of fragments of the calyx and stem of *Platycrinus huntsvillae*. At that, as I will show later, it is not at all certain that the highest part of the range of this crinoid at Bowling Green is older than the upper Ohara; and the upper Ohara according to Weller and Ulrich, and before them Engelmann and Worthen, is indubitably of Chester age. In view of this uncertainty and the acknowledged impracticability of drawing a boundary within the Ste. Genevieve part of the Monte Sana limestone—even such a boundary that could be consistently mapped only by the most expert of stratigraphers—it seems inconsiderate and merely dogmatic to insist on a Chester group whose lower boundary must be left undetermined in quite four-fifths of the territory covered by rocks of this age in eastern United States. Judged solely from the standpoint of practicality, the case is aggravated when we know that the top of the St. Louis, hence also the base of the Ste. Genevieve—at which the Chester-Meramec boundary is herein drawn—is readily determinable throughout this wide areal distribution. And it becomes even worse when we learn that the contact between the St. Louis and the Ste. Genevive at all

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of the seven places in Missouri, Tennessee, and Alabama at which I found it favorably exposed is undeniably unconformable. To all this is added abundant proof showing that the Ste. Genevieve fauna is essentially a unit, so that if its top part is Chester the lower part also should belong to the Chester. Finally, in clinching the argument for the Chester age of the Ste. Genevieve it is only necessary to recall the fact that Worthen, the author of the term Chester group, both before and subsequent to its formal proposal, united the whole of the Ste. Genevieve limestone at Monte Sana with the overlying limestones in his original conception of the group. At that time presumably he referred even the Ste. Genevieve limestone in Monroe County, Ill., to this top group or series of the Mississippian section. This is inferred from the fact that species of crinoids there procured by Worthen from this limestone were sent by him to Hall for determination and subsequently described by the latter in the Geology of Iowa as "Kaskaskia" fossils.*

CHESTER SECTIONS IN ILLINOIS AND KENTUCKY.

PURPOSE.—The main purpose of this and the two succeeding chapters is twofold: (1) To bring out more clearly than appears in Mr. Butts's contribution to the subject certain details of Chester stratigraphy in western Kentucky and southern Illinois that bear on complicated or disputed correlations; (2) to give a fairly comprehensive idea of the regional variations in sequence and character of the Chester deposits in a southeasterly direction from Monroe and Randolph counties, Ill., to the Appalachian Valley. The latter purpose at the same time provides desirable elucidating details of the generalized features shown in the correlated columnar sections.

THE CHESTER SECTION IN MONROE AND RANDOLPH COUNTIES, ILL.—The typical sections of the Chester series are in Monroe and Randolph counties, Ill. The Monte Sana group, comprising the lower formations of the

*In 1882 Worthen changed this reference to St. Louis limestone but without giving reasons warranting the change. See further, this paper.

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series, is best displayed in the southern part of Monroe and in the adjacent northern part of Randolph, the higher formations, corresponding to the Birdsville group, in the southwestern part of Randolph at and near the city of Chester. Combining information published by Worthen,* and later by Weller,† with the results of personal observations, the Chester section in this area may be briefly described, from above downward, as follows:

*Worthen, A. H. Illinois Geol. Survey, Vol. 1, pp. 78-83, 284-291, 1866.
†Weller, Stuart, Illinois Acad. Sci. Trans., Vol. 6, pp. 118-129, 1913; Illinois State Geol. Survey Mon. 1, pp. 23-29, 1914.

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Generalized section of the Chester Series in Randolph and Monroe Counties, Ill.

	Thickness of beds. Feet	Total thickness of formations. Feet
Sandstones of Pennsylvanian age.		
General hiatus and unconformity.		
Chester series.		
Birdsville group.		
Clore formation:		
Interbedded limestones, shales, and occasionally sandstones, the limestone mostly thin-bedded, varying much in character, and in part highly fossiliferous, the shales soft and clayey, or calcareous, or sandy. Fenestrated Bryozoa often very abundant; likewise certain brachiopods, particularly *Spirifer increbescens* and *Composita subquadrata*. The bryozoan part of the fauna greatly like that of the Glen Dean formation, the other fossils more like those in the Menard limestone	25–30	
Arenaceous and calcareous shales with a few thin layers of limestone, all sparingly fossiliferous	0–25	55
Palestine sandstone:		
Sandstone and arenaceous shale, the sandstone forming in some parts heavy beds, in others thin ripple-marked beds, the base of the formation resting apparently unconformably on the Menard limestone. Fossils few, consisting, so far as known, only of fragmentary remains of *Lepidodendron* and other land plants. About		75
Local or general hiatus.		

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	Thickness of beds. Feet	Total thickness of formations. Feet
Menard limestone:		
Thick and thin-bedded, fine-grained, brittle, conchoidally fracturing, bluish-gray limestone, commonly with thin shaly partings. Occasionally one or more of these partings thickens to beds of shale 4 or 5 feet in thickness. Bedding planes of limestones usually uneven or hummocky. Some of the shaly partings are abundantly fossiliferous, and some of the limestone layers are filled with shells of brachiopods and pelecypods; but in other beds fossils are relatively scarce. *Sulcatopinna missouriensis*, a large but thin-shelled pelecypod, is rather common and fairly characteristic. With it are the large and typical varieties of two brachiopods—*Composita subquadrata* and *Spirifer increbescens*—which are represented by smaller and otherwise different varieties in lower formations of the series. *Pentremites* and Bryozoa are not very common in this bed	40–45	
Fine, blue clay shale	25–35	80
Local or general hiatus. (Position of Tar Spring sandstone. A mass of sandstone support to be of this age and interpreted as the filling of a river channel occurs in the bluff at Chester.)		
?Okaw limestone. (Glen Dean formation.)		
Calcareous, greenish or bluish shale and thin, more platy layers of highly fossiliferous limestone ("Plum Creek" beds)	30–40	

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	Thickness of beds. Feet	Total thickness of formations. Feet
These calcareous shales contain the characteristic fauna of the Glen Dean limestone of Kentucky in such abundance and purity that there seems no possible reason to doubt their contemporaneity. In the writer's opinion the propriety of uniting these shaly beds, together with the locally developed underlying sandstone, with the typical main mass of Okaw limestone beneath seems highly questionable. It is believed, in fact, that the two are separated by a stratigraphic hiatus. In any event the Glen Dean part is readily distinguishable from the typical Okaw limestone by not only its fossils but also by its different lithology.		
Sandstone developed locally, apparently corresponding to the Hardinsburg sandstone in southern Illinois and western Kentucky	0–22	
Probable hiatus.		
Okaw limestone (typical).		
Four or five conspicuous limestone horizons alternating with usually thinner beds in which calcareous shales predominate. About	150	150 or 212
The Okaw limestones are mostly of grayish color but vary greatly in texture, some being crystalline, others oolitic, and a few relatively fine grained and sometimes cherty. A rather persistent, grayish oolitic bed occurs about 60 feet above the base, and a similar though usually whiter oolite has been observed at several localities approximately 40 feet be-		

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	Thickness of beds. Feet	Total thickness of formations. Feet
neath the top. These oolites contain a fauna of small pelecypods and gastropods that are scarcely if at all distinguishable from preceding Gasper, Ste. Genevieve, and Spergen occurrences of the same types.		
Fossils occur in both the shales and the limestones of the Okaw formation, and in many places they are abundant. Except in the oolites, the fauna is typically Chesterian in composition. Nevertheless it includes many species that so far have been found only in this formation. Near the top is a zone with the large blastoid, *Pentremites sulcatus*, which has not been observed to the south and southeast of the Randolph County basin, nor in any other horizon of the Chester series. Another well characterized fossil zone is at the base of the formation as now constituted. This is marked by two brachiopods, *Martinia contracta?* and *Productus inflatus*, neither of which has been found either higher or lower in Randolph County.*		
Probable break		

*The fact that these two shells are similarly associated in Breckinridge County, Ky., in a bed of limestone directly under the Cypress sandstone has raised the question whether the limestone containing them in Randolph County may not be separated from the overlying beds of the Okaw by a stratigraphic break. Under my interpretation of the time relations of the Okaw—my view being that the Okaw is represented to the south by the Cypress sandstone—it is unnecessary, even when the Martinia beds in the two states are correlated, to assume any such break. We need to assume only that both occurrences are either very late Gasper or preferably early Cypress in age; and in the latter event that Cypress sandstone deposition began somewhat earlier in, say Crittenden and Caldwell counties, Ky., than elsewhere, and that during the same early Cypress stage fossiliferous lime muds were being laid down to the east in Breckinridge and Hardin counties, Ky., and to the north in Randolph County, Ill.

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	Thickness of beds. Feet	Total thickness of formations. Feet
Monte Sana group.		
Ruma formation:		
Red, blue and gray shale with an irregular bed of sandstone near or above the middle. The shales seem to be unfossiliferous, but fragmentary remains of lepidodendroid plants have been found in the sandstone.†	25–40	40
Paint Creek formation:		
Bluish calcareous shale and limestone, both highly fossiliferous. Among the common fossils are *Zaphrentis spinulifera*, 10 to 12 species of *Pentremites*, most notable of which are *P. symmetricus*, *P. gemmiformis*, and *P. planus*, *Mesoblastus glaber* var., many Bryozoa including species of *Fenestella*, *Archimedes*, *Lyropora*, *Rhombopora*, and *Cystodictya*, *Spirifer increbescens* (thin-shelled, long-hinged variety), and *Spiriferina spinosa*	35	
Red clay bed, poorly stratified and without fossils	22	
Blue or gray shale occasionally with thin calcareous layers	3–4	61
Yankeetown chert:		
White, gray, or yellowish, often sandy chert (the rock probably is a siliceous limestone under deep cover), some of the layers largely made up of comminuted organic remains, particularly of Bryozoa		20

†The Ruma formation probably is represented in Kentucky by shaly sandstone or red shale locally found at the top of the Gasper oolite. See Mr. Butts' chart, sections No. 5 and 28.

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	Thickness of beds. Feet	Total thickness of formations. Feet
Renault formation: An exceedingly variable association of sandstones, red, blue, or gray shales, and limestones, many of the calcareous beds containing more or less abundant marine fossils whereas stems of lepidodendroid plants are not uncommon in the sandstones. The Renault fauna includes many characteristic crinoids and some blastoids of the genus *Pentremites*, practically all of the latter being held in common with the overlying Paint Creek formation. The crinoids, however, seem to be confined to this zone. They include at least four species of *Talarocrinus* that have proved very useful in correlation. Among the Bryozoa a species of *Lyropora* is abundant, but *Archimedes* is as a rule rare and often wanting entirely.....	40–100	100
Aux Vases sandstone: Massive beds of fine-grained, often cross-bedded sandstone, the freshly broken rock white or light yellowish-brown, but surfaces after long exposure to the weather take on a darker, reddish-brown color. Maximum thickness about		80
Stratigraphic break.		
Ste. Genevieve limestone: More or less massive beds of white oolite and light-blue, fine-grained limestone. commonly including a zone 10 feet or more in thickness that is decidedly arenaceous and cross-		

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	Thickness of beds. Feet	Total thickness of formations. Feet
bedded, and part of which may weather to a porous sandstone. Many of the layers are fossiliferous but only a few afford good specimens in large numbers. The fauna as a whole may be called a recurrence of the fauna of the Spergen oolite, but many of the long enduring species in the Ste. Genevieve are distinguishable from their Spergen ancestors. However, with these are many other species that are characteristic of this formation. The thickness of the formation varies greatly, being, indeed, absent entirely in a few places. Its maximum in Randolph and Monroe counties probably does not exceed.....		100
Maximum thickness of Chester series....		813
Stratigraphic break and unconformity.		
Meramec series.		
St. Louis limestone.		

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PROBABLE REPRESENTATIVES OF THE TAR SPRINGS AND HARDINSBURG SANDSTONES IN THE SECTION AT AND NEAR CHESTER, ILL.—One hundred yards or so north of the road from the city of Chester to the station at bottom of bluff is a peculiar deposit of sandstone. The base of the mass of sandstone lies but little above the top of what is here designated as the "typical" Okaw limestone, and its sides butt against the sloping edges of the shale and limestone bed here referred to the Glen Dean. Apparently the mass fills a channel excavated in the Glen Dean. Over it comes the Menard limestone. If these observations are correct, the sandstone must be younger than the Glen Dean and older than the Menard. Accordingly, it is interpreted as the arenaceous filling of a river channel formed during the time represented in the region adjacent to Ohio River by the widely displayed Tar Springs sandstone.

At Cole's mill, a short distance south of Chester, a section was measured that has an important bearing on the correlation of the Okaw limestone with the Chester formations in Kentucky. The beds observed here are as follows:

Section of Chester beds at Cole's Mill, south of Chester, Ill.

		Thickness in feet.
8.	Impure limestones and shale, poorly exposed, evidently representing the lower part of the Glen Dean formation	20
7.	Sandstone, moderately thick-bedded in lower half, thinner and almost shaly toward the top	22
6.	Dark-blue, arenaceous, ripple-marked shale	3
5.	Granular fossiliferous limestone, containing *Pentremites sulcatus* and species of Lyropora	2.5
4.	Dark-colored shale	4
3.	Fine-grained and shelly argillaceous limestone	6
2.	Fossiliferous calcareous shale, containing *Lyropora*, *Archimedes*, and other fossils	2
1.	Moderately fine-grained, shelly and oolitic limestones, without shaly partings. The upper layers crinoidal and more massive than the remainder. The oolites show occasional bands that are filled with fossils of a recurrent Spergen fauna. About 20 feet of these limestones were seen between the mill and water level in the Mississippi, and about 10 or 15 feet of still lower beds half a mile below the mill; in all say	30

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In the exposure half a mile below Cole's mill an approximate thickness of 35 feet of limestone without shale is shown. Over this is 2 feet of dark shale, evidently corresponding to bed 6 at the mill. This is succeeded by arenaceous limestone and sandstone of undetermined thickness. The fossiliferous beds 2 and 5 of the mill section were not observed at this point.

The sandstone in these sections seems to represent the Hardinsburg sandstone of southern Illinois and western Kentucky. How much of a break separates the base of this sandstone from the underlying typical Okaw limestone is undetermined. However, the absence of the *Pentremites sulcatus* zone, in the section half a mile south of Cole's mill, suggests that the top beds of the Okaw may have been cut out in places preceding and during the deposition of the Hardinsburg sandstone elsewhere. In accord with this suggestion is the fact that *Pentremites sulcatus* has not been reported from many places even in Randolph County.

THE CHESTER SERIES IN JOHNSON, POPE, AND HARDIN COUNTIES, ILL., AND CRITTENDEN AND LIVINGSTON COUNTIES, KY.—Though varying considerably in detail from place to place, the stratigraphic sequence of beds comprised in the Chester series in the counties bordering on the north and south sides of the Ohio west of Rosiclare, Ill., is yet sufficiently uniform in lithologic and faunal characters to enable one to recognize the several formations with reasonable definiteness and certainty. However, as the region is profusely faulted, great care is required to avoid serious errors in correlation of outcrops.

The following section is compiled from many sections measured especially on the south side of the river, the several beds in the exposures on the north side having been, as a rule, merely recognized as corresponding to those which had been more closely investigated at localities in Livingston and Crittenden counties. In general it may be said that the sandstones of the series become thinner, or at least more shaly, in going southward from Ohio River. This diminution in quartzitic content is particularly notable in the sandstones above the Cy-

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press sandstone, namely, the Hardinsburg, Tar Spring, and Palestine sandstones. The limestones and calcareous shales also vary considerably in thickness and lime content, but the variations in these beds do not seem to be in any given direction. Some, indeed, may grow thicker in a southerly direction—perhaps partly at the expense of the sandstones. At any rate the aggregate thickness of the Chester formations decreases to the south from Johnson and Pope counties in Illinois whereas the proportion of limestone increases.

The greatest variability is in the formations of the Birdsville group, and particularly in the sandstone members. Comparisons of numerous sections taken in Livingston, Crittenden, and Caldwell counties during the progress of my early work in western Kentucky indicate rapid variations in thickness and also the character of the sandstones. Thus thicknesses of from 50 feet to 80 feet of the Hardinsburg, the Tar Springs, or the Palestine sandstone may drop to less than 15 feet in a few miles. Some of this variability may be accounted for by assuming lateral transition into shales, but surely not all of it.

Another source of trouble concerns the top of the series. Though there is but seldom any difficulty in deciding where the Chester beds cease and the Pennsylvanian begins, it is an altogether different problem to fix the position of the top bed of the Chester in the generalized section. In some places it is a cherty limestone, in others a limestone without chert, in yet others a shaly limestone, or a sandy bed, or more rarely a shale. Evidently this variation is caused mainly by local differences in amounts removed from the top of the series by pre-Pennsylvanian erosion. So far as known, this erosion seldom if ever in this region cut completely through the Clore formation, but relief of 50 feet to possibly more than 100 feet in the Chester floor on which the Pennsylvanian deposits were laid down is not uncommonly indicated. The highest Chester bed known is a more or less profusely cherty limestone. But this, together with one or more underlying beds, is often wanting, the succeeding Pennsylvanian conglomerate sandstone in such cases being in contact with some lower bed of the Clore;

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and most certainly it is no easy matter to determine accurately which bed it is.

Reasonable certainty in correlating the Birdsville formations in western Kentucky and southern Illinois is possible only by tracing one or another of the several formations from place to place. At the same time the fossil contents of the beds must be carefully scrutinized and collected, for their testimony alone is dependable when we enter the faulted region. The fossils of the Glen Dean formation are especially useful in establishing a datum plane within the mass of the Birdsville from which we proceed both upward and downward in the section. Because of its practical value in correlating the formations, the Glen Dean fauna is listed in approximate completeness on later pages.

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Generalized section of the Chester Series in Livingston and Crittenden Counties, Ky.

	Thickness of beds Feet	Total thickness of formations. Feet
Pennsylvanian: Sandstone and conglomerate, 250 feet, capping Hardins Knob, 2 miles southwest of Sheridan, Crittenden County, Ky.		
Mississippian.		
Chester series.		
Birdsville group.		
Clore formation:		
Cherty limestone, chert often in thick plates and commonly of red color. Best displayed in slope of hill 3 to 4 miles southwest of Salem. Shown also a mile or two southwest of Carrsville	0–20	
Green clay shales, locally with layers of limestone	0–30	
Rather heavy beds of grayish-blue, compact or sub-granular limestone with shale partings varying in thickness, usually fossiliferous	0–30	
Yellowish-green or purple often arenaceous shale with plates of fossiliferous limestone and occasionally sandstone	0–90	
Limestone, thick-bedded or flaggy	0–30	
Dark-gray, greenish, or purple, unfossiliferous shale	8–20	50–210
Palestine sandstone:		
Sandstone, sometimes white and solid, at other times soft or shaly	10–60+	60+
Probable stratigraphic break.		
Menard limestone:		
Limestone in beds of varying thickness, usually compact in texture, sometimes shaly, in part highly fossiliferous	30–110	110

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	Thickness of beds. Feet	Total thickness of formations. Feet
Tar Spring sandstone:		
Variable in character	5–80	80
Probable stratigraphic break.		
Glen Dean limestone:		
Mainly thin-bedded, blue and gray, compact or sub-granular, occasionally crinoidal limestone, interbedded, especially in the middle part, with dark-gray, blue, or green shale. Some of the limestones in the lower part commonly somewhat cherty and occasionally sandy, the fossils in the cherty layers often weathering out as siliceous pseudomorphs. Most of the limestone layers and also many of the shaly beds are profusely fossiliferous.	50–100	100
Hardinsburg sandstone:		
Varying from hard and massive to soft and more or less shaly	40–75	75
Probable stratigraphic break.		
Golconda formation:		
Consists of interbedded limestones and shales, both varying greatly in character, color, and thickness of beds. As a rule the upper and lower thirds contain many beds of limestone, whereas the middle third consists mainly and in some places almost entirely of shale. The limestones vary in texture from granular or even crinoidal to compact and more or less argillaceous; and one of 2 to 5 feet thickness above the middle of the formation is sufficiently ferruginous to form possibly valuable deposits of ochre		

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	Thickness of beds. Feet	Total thickness of formations. Feet
and umber. The shales are mostly soft and of green colors in the middle and upper thirds, with occasionally some of reddish tints. In the basal third the shales commonly are dark. Most of limestones and shales are fossiliferous and some are filled with animal remains. (See lists given on later pages.) Variations in the top suggest erosion prior to deposition of the Hardinsburg sandstone; and the absence of the lowest fossil zone in places may indicate overlap or local persistence of sand deposition which would be included with the underlying Cypress sandstone.....	100–140	140
Cypress sandstone, Engelmann, 1863 (not Ulrich, 1905):		
Moderately heavy-bedded and often cross-bedded, flaggy sandstone, usually white, yellow, or brown in color, varying in texture from coarse to fine-grained; also includes some arenaceous shales. The town of Marion is built on this sandstone; and it outcrops over most of the area between Crayneville and Mexico. As a rule this formation forms wider and less uneven surfaces than any other Chester sandstone	70–110	110
Probable stratigraphic break.		
Monte Sana group:		
Ridenhower shale:		
Satisfactory exposures of this shale are rare in Crittenden and Livingston counties. As a rule it forms a rela-		

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	Thickness of beds. Feet	Total thickness of formations. Feet
tively flat, bench-like area between a lower, rather steep escarpment of Aux Vases sandstone and a higher, relatively gentle slope which is made by the Cypress sandstone. In a previous work* these benches were included in indefinitely outlined areas referred to as "Undifferentiated Chester." Incomplete outcrops of the Ridenhower shale were observed above the Aux Vases sandstone ("Cypress" sandstone of Ulrich, 1905) southeast of Carrsville, in the area 6 to 8 miles north of Smithland, and in the areas to the north and west of Marion. So far as known, the Ridenhower in these areas is essentially like its outcrop in the bluff on the north side of the Ohio below Golconda.† Here it consists of a slightly arenaceous and in part calcareous shale approximately 50 feet in thickness		50
Stratigraphic break.		
Aux Vases sandstone (Cypress sandstone, Ulrich, 1905): Massive to thin-bedded, generally fine to medium-grained, rarely coarse, quartzose sandstone. Quartz and other pebbles, of small size, rarely seen in its lower part. Sometimes it		

*Ulrich, E. O., and Smith, W. S. T. The lead, zinc and fluorspar deposits of western Kentucky. U. S. Geol. Survey Prof. Paper 36, maps, Pls. II., VIII., 1905.

†At one place in Crittenden County—about 2 miles south of Crayneville—this interval is occupied by 33.5 feet of limestones, shaly in the lower half and including a 5-foot bed of sandstone near the top and a 4-foot bed of oolite beneath the sandstone. Over this limestone is the Cypress sandstone, beneath it the Aux Vases sandstone.

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	Thickness of beds. Feet	Total thickness of formations. Feet
is soft and friable but usually the grains are well cemented. Not infrequently portions of the upper half are thin-bedded and flaggy and then commonly cross-bedded. Argillaceous layers are uncommon. The lower part seems always massive. The color varies but is commonly of a light-brown exteriorly and nearly white in fresh fractures	50–80	80
Stratigraphic break.		
Ste. Genevieve limestone.		
Ohara member:		
Light and dark-gray or bluish, subcrystalline, generally massive, in part cherty limestone inter-bedded with brownish, earthy, compact limestone and usually thin layers of calcareous shale, most of the beds fossiliferous (*Lyropora*, *Polypora*, *Productus inflatus*, and several species of *Pentremites*), the top apparently eroded so that different layers are in contact with the overlying Aux Vases sandstone	5–35	
Greenish, soft, calcareous shale and thin-bedded limestone, extremely fossiliferous, *Amplexus geniculatus* characteristic; interruption of sedimentation locally suggested at its base	8–12	
Massive, impure, gray, mainly compact limestone, some layers weathering blocky, others semi-oolitic all sparingly or but moderately fossiliferous, *Diaphragmus elegans* abundant locally	20–30	

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	Thickness of beds. Feet	Total thickness of formations. Feet
Oolitic and fine-grained limestone, fossils few	10–20	
Maximum thickness of Ohara member		97
Thickness of the Ohara decreases to the southward from Ohio River at Rosiclare, Ill., where it reaches the observed maximum of about 102 feet. In some places the upper bed is absent entirely.		
Rosiclare sandstone: Laminated, calcareous, and of greenish-gray color in unweathered condition, reddish, soft, and porous on weathered surfaces	2–9	9
Fredonia oolitic member: Mainly oolitic limestone, white and light gray, varying from thin-bedded to massive; interbedded with crinoidal, crystalline, and fine-grained limestones, the last commonly yellowish or brown; near the middle often a flaggy deep-blue, semi-crystalline limestone; here and there a shaly layer. Base not observed		113
Total thickness of Ste. Genevieve limestone		209+
Total maximum thickness of Chester series, about		1200
Probable stratigraphic break. (Contact with underlying St. Louis limestone not observed in this region. Where seen in other places it exhibits unmistakable criteria of subaerial erosion and unconformity.)		
Meramec series St. Louis limestone.		

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Section of the Chester Series in Caldwell County, East of Princeton, Ky.

This section is made up mainly from observations of cuts along the railroad and nearby natural exposures eastward from Princeton to Dawson Springs. The Glen Dean limestone and Hardinsburg sandstone are faulted out where they would have crossed the railroad, but they may be seen at many places to the north of the railroad in the triangle bounded by lines connecting Ruth, Creswell and Lewistown. The Gasper oolite part of the section is improved by information procured in the northwestern corner of Christian County where good exposure, showing both underlying and overlying formations are to be seen along the wagon road from Princeton to Hopkinsville.

	Thickness of beds Feet	Total thickness of formations. Feet
Pennsylvanian.		
Great stratigraphic break.		
Mississippian.		
Chester series.		
Birdsville group.		
Clore formation:		
An exceedingly variable sequence of beds, locally with red chert at the top and including soft marly shales, varying in color from yellow or green to purple, limestones in thick and thin beds, and more or less of sandy shales and clay-stones. (See detailed sections)	40–60	60
Palestine sandstone:		
Mainly yellowish sandstone varying from massive to thin-bedded or even shaly	20–60	60
Menard limestone:		
More or less lighly argillaceous limestone, much of it of concretionary structure, also including some shale with claystone or calcareous nodules; almost entirely unfossiliferous	25	
Mainly argillaceous limestone, bluish or gray in color, massive fresh but breaking into shaly lamellae under		

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	Thickness of beds. Feet	Total thickness of formations. Feet
weather, rather highly fossiliferous. (See list.)	25	50
Tar Springs sandstone: Yellow or white massive or thick-bedded sandstone	14–50	50
Glen Dean formation: Interbedded fossiliferous limestones and shales, the beds of both varying greatly in character and thickness. Under proper conditions some of the relatively thick beds of limestones are cherty. Contains a large fauna, many of the species being characteristic. (See lists)	45–65	65
Hardinsburg sandstone: This formation is not prominently developed in Caldwell County. As a rule it seems to be more shaly than usual and apparently also thinner. About		40
Golconda formation: This formation also seems but weakly developed in eastern Caldwell County. What there is of it is limestone with thick or thin shale partings. Fossils are not very abundant except in the upper fourth. Apparently only the upper portion of the formation as developed in the type section at Golconda, Ill., where it reaches a thickness of 140 feet, is represented in Caldwell County by these limestone and shale beds. The lower part probably is represented here in part or whole by beds of unfossiliferous sandstone and arenaceous shale that are		

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	Thickness of beds. Feet	Total thickness of formations. Feet
referred to the underlying Cypress sandstone. Thickness of Golconda limestone in eastern Caldwell County about		50
?Cypress sandstone (perhaps lower Golconda):		
The following section of arenaceous beds, shown in railroad cuts between Scottsburg and Claxton, probably includes beds at top that correspond in age to limestone and calcareous shale in Crittenden and Livingston counties and cross the Ohio in Pope County, Ill., there referred to the Golconda formation.		
Shaly sandstone, 10 feet exposed, its top separated from the lowest limestone of the overlying Golconda formation by an interval sufficient to hold another 10 feet of beds, the two together	20	
Massive bed of yellowish sandstone	3	
Greenish arenaceous shale	60	
Shaly greenish sandstone	12	
Irregularly bedded, fine-grained, yellow and reddish sandstone	26	
Red residual clays after limestone, remnants of same filled with fossils, especially fragmentary remains of crinoids and blastoids	3	(124)
This limestone may indicate the true base of the Golconda formation		174
Cypress sandstone:		
Greenish shale with thin irregular layers of fine-grained sandstone	36	
Massive sandstone	6–8	

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	Thickness of beds. Feet	Total thickness of formations. Feet
Thin-bedded sandstone	2	
Shaly sandstone varying in color from greenish to yellow	18	
Soft green shales	26	
Cherty and conglomeratic, calcareous and ferruginous sandstone, with fossils, mainly fragmentary crinoids and *Spirifer increbescens*	3	
Shaly sandstone	14	
Yellowish fine-grained sandstone	16	
Shaly sandstone	40	(163)
Total thickness of Cypress sandstone including possible arenaceous equivalent of lower and middle parts of Golconda formation		287
Gasper oolite (in hill south of railroad, about 3 miles east of Scottsburg):		
Oolitic limestone, poorly exposed, about	5	
Shaly and thin-bedded sandstone locally fossiliferous	25	
Impure, light-gray or drab, compact limestone full of small fossils including *Pentremites*	8	
Sub-crystalline, gray limestone, partly crinoidal or pentremital with some rather thin layers of oolitic texture, fossiliferous but good specimens uncommon except in residual clays	30–33	
Greenish calcareous, marly shale with thin plates of limestone, both highly fossiliferous (the shaly middle bed of the formation)	6	
Dark-gray to blue crinoidal limestone, with some lighter colored oolitic layers; *Pentremites godoni, Pentremites pyriformis, Composita trinuclea,* and *Cleiothyridina sublamellosa* abundant	22	

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	Thickness of beds. Feet	Total thickness of formations. Feet
Covered space, probably limestone, about	8	
Massive, light-gray, crystalline limestone, full of broken shells of brachiopods	4	
Soft shale or marl, gray, green and yellow, with thin streaks of coal, to top of underlying Aux Vases sandstone	5	
Total thickness of Gasper limestone		116
Aux Vases sandstone:		
Sandstone, commonly in thin layers, often cross-bedded in upper part and massive in lower	30–50	50
Ste. Genevieve limestone:		
Ohara member (see detailed section)	75–101	
Rosiclare sandstone	1–4	
Fredonia oolite member: Largely made up of various shades and grains of oolite, generally in massive beds. These are interbedded with compact, sometimes almost lithographic limestones, also with other more impure to quite shaly limestones, and more rarely with shale and marly clays. A persistent, porous, cherty bed in the upper 60 feet, and more solid nodular cherts here and there also in the lower 50 feet. Many of the beds are fossiliferous but large collections are procurable only locally in the oolites. The *Lithostrotion harmodites* and its associated fauna occurs 22 to 28 feet beneath the top. Base not seen. Total thickness observed, about	100	205
Total thickness of Chester series in Caldwell County		933
Meramec series.		
St. Louis limestone: Seen to west and south of Princeton.		

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DETAILED SECTIONS OF CHESTER FORMATIONS IN LIVINGSTON, CRITTENDEN, AND CALDWELL COUNTIES.

General Discussion.—That the reader may acquire a clearer idea of the character of the most important of the Chester formations in western Kentucky, and at the same time an appreciation of the extreme variability in lithologic features that must be guarded against to avoid error in recognizing and correlating the several zones, it has seemed worth while to add a number of selected detailed sections of the Clore, Glen Dean, Gasper, and Ste. Genevieve formations.

The three sections of the Gasper show how this formation thins in a northwesterly direction from Christian County by overlap and loss of beds from below. The last in Crittenden County indicates, further, that the overlapping upper part of the formation grows more shaly in going westward; and this fact supplemented with our information respecting the Ridenhower shale as developed in central Crittenden County and thence westward in Livingston County and northward across the Ohio in southern Illinois, makes it reasonably certain that the Ridenhower shale corresponds in age to, and probably passes into the upper, often shaly part of the Gasper oolite.

The Ste. Genevieve limestone sections show that the Ohara member loses beds from the top in a southwesterly direction from a line passing through or near Rosiclare, Ill., on the northwest, and Princeton, Ky., on the southeast. This loss affects at least the in part cherty upper limestones of the Ohara which have a thickness of about 50 feet at Rosiclare and 28 feet at Cedar Hill, 2 miles east of Princeton. These beds pass out of the section in places so rapidly that pre-Aux Vases erosion is suggested as a locally important contributing cause of its absence. They are wanting, for instance, in the section directly north of Princeton where the shaly bed that in Cedar Hill lies 28 feet beneath the top of the Ohara is in contact with or but a few feet be-

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neath the base of the Aux Vases sandstone. Similar conditions were observed also in the vicinity of Marion. However, this relatively non-resistant shale bed is widely distributed to the southwest of the line mentioned, so that we are warranted in assuming that slight warping, and consequent local or partial retreat of the Ohara sea, rather than pre-Aux Vases erosion is the main reason for the small development or entire absence of the uppermost zone of the Ohara in many places. The same conclusion is indicated by the fact that even in those places in which the top limestone of the Ohara is thinly developed it commonly includes the cherty layers which belong in the upper part of the zone in areas wherein it attained its fullest development.

Comparison of the following and other sections of the Ste. Genevieve limestone exposures establishes, further, the absence of any stratigraphic boundary within the Ohara member that can possibly be used as a practical plane of separation between distinct lithologic or stratigraphic units. Following deposition of the Fredonia member, the succeeding sedimentary history of the Ste. Genevieve, like that of all the other Chester formations, is characterized by frequent local to general oscillation throughout its extent. Besides, the oscillations were differential and not eustatic, so that relative thicknesses of beds or zones is not maintained from place to place. On the contrary, with the total thickness of the member approximately the same at two places, the individual beds or zones commonly differ widely in thickness and, I may add, also in lithic character.

The sea in which the Ohara was laid down, though evidently of wide expanse, was nevertheless very shallow; and oscillations in such a sea necessarily must have effected local interruption of sedimentation, either with or without complete emergence of such areas. Where these interruptions occurred slightly irregular contacts and even conglomerates are to be expected. But the conglomerates most probably would contain only indigenous pebbles—in other words, be of the intraformational type—and the under, possibly eroded, surface would be without any of the criteria indicating long emergence and consequent subaerial decomposition and wear. This,

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in fact, is the character of all of the so-called "breaks" and "unconformities" observed by me in the Ohara member of the Ste. Genevieve limestone.

Moreover, these breaks are not at the same horizon in the several sections. In the section at Rosiclare, Ill., it lies at the base of the shale member (faunal zone 3). In the section of Cedar Hill, near Princeton, on the contrary, the "conglomerate bed" lies about 40 feet beneath the supposedly corresponding shale (at the base of faunal zone 2). In many other sections no evidence whatever of a break has been observed at either of these positions.

When the shale and sandstone beds have passed entirely out of the Ste. Genevieve limestone section, as they do not far east and south of Hopkinsville, Ky., no more sedimentary breaks are observable in the formation. Beyond the mentioned place it is very difficult if not impossible to say just how much of the formation corresponds to the part that overlies the Rosiclare sandstone in Caldwell and Crittenden counties. And yet it seems certain that the Ste. Genevieve limestone of, say, the vicinity of Bowling Green, does include beds corresponding in age to at least a part of the upper member that in western Kentucky and southern Illinois is definitely separable from the Fredonia member by the Rosiclare sandstone. However, the same uncertainty is encountered throughout the great area stretching from Bowling Green to Huntsville, Ala., and to the Appalachian Valley in east Tennessee and southwestern Virginia. Indeed, in this same great area the Aux Vases sandstone also is wanting so that the more or less prevailingly oolitic limestones of the Ste. Genevieve are succeeded directly by other, in part oolitic, limestones that are of the age of the Gasper oolite of Kentucky; and it is then no easy matter to decide just where the boundary between the two should be drawn.

The impracticability of any endeavor to limit the Chester series below at any horizon above the base of the Ste. Genevieve will become obvious enough when conditions prevailing in southeastern Kentucky, Tennessee, and Alabama are granted equal consideration with those in the Mississippi Valley in the settlement of this taxonomic problem.

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DETAILED SECTIONS OF THE CLORE FORMATION.

Section of the Clore Formation, Palestine Sandstone, and Menard Limestone East From Tribune, Crittenden County, to Top of Hill.
(From notes and measurements by Charles Butts.)

	Feet.
Pennsylvanian sandstone.	
Mississippian.	
Chester series.	
Clore formation:	
Green clay shale at top; just under this chert, with remains of crinoids, apparently in place	1–2
Concealed, surface with chert debris	19
Green clay shale at top with occasional layers of similar shale showing in remainder of space	25
Limestone, in thick ledges; *Bellerophon* sp. abundant, observed also *Eumetria* sp., *Orthotetes* sp., and small *Composita*	20
Green clay shale at top, remainder not exposed, probably all shale	20
Sandstone, ferruginous, soft, fossiliferous, shells of *Schizodus* abundant	5
Shale	5
Concealed, probably shale	10
Soft, green shale with limestone layers, fossiliferous; large *Composita subquadrata*, *Spirifer increbescens*, *Eumetria* sp., *Schizophoria?* sp.	30
Concealed	20
Sandstone and shale	2
Possible small gap in section	?
Limestone, thick-bedded, but weathers to 2 to 6-inch flags	35
Shale	10
Concealed	10
Palestine sandstone:	
Sandstone debris, indicating thin-bedded sandstone and arenaceous shale	40
Menard limestone:	
Limestone	25
Concealed, surface indications of shale and shaly or argillaceous limestone	45
Limestone, with *Sulcatopinna missouriensis* fairly abundant about 10 feet above base of exposure, to creek level at Tribune	40

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According to Mr. Butts's estimates the Clore in this section slightly exceeds 210 feet in thickness. This is considerably greater than in following sections taken at localities in Caldwell County. It must exceed also the thickness of the formation near Gladstone, 5 or 6 miles north of Tribune, where the Pennsylvanian sandstone rests on a much lower bed of the Clore than at Tribune. A similarly great thickness of the formation was noted by me on the south slopes of Pilot and Cedar knobs, 3 to 4 miles south of Tribune. The Palestine sandstone in this vicinity scarcely attains the average thickness for this formation. The Menard limestone, however, like the Clore, is uncommonly thick.

SECTION AT QUARRY SOUTHWEST OF GLADSTONE.—Beside the railroad track, about 2 miles southwest of Gladstone and 7 or 8 miles northeast of Marion, is a quarry, now probably abandoned but formerly known as the Giles quarry, in which is shown an uncommonly thick development of limestone in the upper part of the Clore formation. The base of the formation is not exposed here, but the overlying Pennsylvanian deposits are shown in the low hill above the quarry. Details of this limestone were noted as follows:

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Incomplete Section of the Clore Formation in Crittenden County, Near Gladstone.

	Feet.
Pennsylvanian:	
Sandstone, partly exposed on slope and summit of hill; contains a thin bed of coal, 4 to 5 inches thick, 30 to 40 feet above the base. About	50
Mississippian.	
Chester series.	
Clore formation:	
Shaly limestone and clays	2–3
Dark grayish-blue, compact, argillaceous limestone, the layers varying from 6 inches to 3 feet in thickness, sparingly fossiliferous	9
Light-blue, subcrystalline limestone, in layers 6 to 16 inches thick	7
Drab-colored, argillaceous limestone	2
Blue, more or less impure, compact limestone, the layers varying from 3 to 12 inches thick, appearing shaly after long exposure to weather. At top a 12-inch layer with small, rounded masses resembling *Solenopora* but probably an undescribed sponge. Other layers in upper half contain specimens of an new species of *Chaetetes*, and most of them have a large *Bellerophon*. At the base a few inches of shaly limestone and calcareous shale filled with brachiopods—mainly *Composita subquadrata* but including species of *Productus*, *Camarophoria*, and *Dielasma*—and Bryozoa, most of them of fenestellid genera. Thickness of bed	6–7
Shale, green, marly	7
Shale, purple, to base of exposure	3

It is to be observed that both the cherty top bed of the full Clore section and the arenaceous shale bed which belongs between it and the underlying main limestone zone of the formation are absent here. Also that the Pennsylvanian sandstone at the top of the section is not the same bed—whether older or younger is not decided—as the one with the quartz pebbles which to the south at Claxton and in the Pennsylvanian outliers in Crittenden County follows the Chester. The limestones of this section evidently correspond to the upper, 20-foot bed in Mr. Butts's section at Tribune.

Measuring in a straight line about 10 miles south-

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east from Giles's quarry to a point nearly a mile north of Creswell postoffice, and also 2½ miles east on the Princeton and Shady Grove road, nothing like the limestone beds of the section at Tribune and in Giles's quarry was observed. At these places the Clore seems to consist almost entirely of shale and flaggy, in part fucoidal sandstone, in all 100 feet or so in thickness. At its base and resting on yellow or white, brown-weathering sandstone supposed to represent the Palestine sandstone, is 5 feet or more of mainly light-blue or gray, compact limestone containing *Pentremites* and fragments of crinoids, the basal layer being a yellowish unfossiliferous claystone. About 60 feet above this in the Creswell section, and hardly more than 30 feet at the more eastern outcrop, is another limestone. This varies from 5 to 8 feet in thickness, is more or less arenaceous in composition, and on weathering liberates a conspicuous quantity of blocky, fossiliferous chert. Possibly the lower of these two limestones represents the upper layers of the limestone in Giles's quarry, in which case the older beds of the Clore would be absent here. However, it seems just as likely that they correspond to the lower limestone of the Clore in the sections east of Tribune.

Limestone again becomes prominent in the section 6 miles southeast of Creswell, being shown along the Princeton and Wilsons Bridge road three-fourths of a mile to 2 miles south of Liberty church. The bottom of the limestone in this section, which extends downward into the Menard, is found at a point about 7 miles north of Princeton. The upper part is seen in ascending the hill a mile or more farther north. At these two places the following section was noted:

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Section of Upper Part of Chester Series 7 to 9 Miles North of Princeton.

	Feet.
Pennsylvanian.	
Sandstone, brownish, fine to coarse-grained, of undetermined thickness.	
Mississippian.	
Chester series.	
Clore formation:	
Chert, reddish, from decomposed limestone	2
Fucoidal sandstone, greenish	1
Chert containing some fossils	2–3
Lenticular bed of gray, fossiliferous limestone	0–1
Shale or marl, soft, light-green in color	5
Shale or marl, soft, of dark purple color	6
Shale, soft, green	1
Argillaceous limestone, yellowish or drab in color, with a few remains of Bryozoa	4
Limestone, compact, impure, light-drab, without fossils so far as observed	5
Yellowish, highly argillaceous limestone	2
Limestone, gray or drab, impure, compact	3–4
Yellow, laminated, porous, calcareous claystone	3
Marly shale, of yellow color in the middle and green at the top and bottom	8
Soft shale with a thin layer of fossiliferous limestone near base	6
Total thickness of Clore formation	51
Palestine sandstone:	
Thin-bedded, in part shaly sandstone, exposed 25 feet, in all perhaps	50
Menard limestone:	
The lower 18 feet fossiliferous, exposed a mile or more south of the above section. Under this a sandstone, presumably the Tar Springs sandstone.	

Other outcrops of the Clore were observed several miles to the southeast in the slopes of the valley of Flynn Fork. In these limestone content of the formation has increased yet further, being here not greatly inferior in proportion to that found in Crittenden County at Giles's quarry. The section in this valley, excepting that it contains more beds at the top, is considerably like that studied at Claxton station, 6 miles east of Princeton, an account of which follows:

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Section of the Clore Formation at Claxton Station.

	Feet.
Pennsylvanian.	
Bluff 70 to 100 feet in height, consisting of brownish, rather coarse sandstone, with abundant rounded quartz pebbles in lower half.	
Mississippian.	
Chester series.	
Clore formation:	
Soft shale, slightly arenaceous, the basal part bluish in color with thin irregular plates of fossiliferous limestone, the middle and upper parts green and finally yellow. The pelecypods listed on page 236 collected in the basal part	8
Limestone, blue, fine-grained, tough, in five layers, the top one 12 inches, the next 6 to 8 inches, the third 22 to 26 inches, the fourth 6 inches, the fifth 16 to 18 inches, all more or less fossiliferous: *Orthotetes kaskaskiensis*, *Camarophoria explanata*, *Spirifer increbescens*, *Composita subquadrata*, *Bellerophon* sp., and a large *Nautilis*	5–6
Soft yellow and green shales with thin uneven layers of extremely fossiliferous limestone. Most of the fossils listed on page 236 from this bed	10
Limestone, bluish and gray, compact, in layers of 6 to 20 inches	4–5
Mainly soft, bluish shale with occasional thin layers of indurated calcareous clay and impure limestone, so far as known unfossiliferous (shown in gully a short distance west of station)	30–40
Total thickness of Clore formation about	64
Sandstone, 5 feet shown, supposed to be the top of the Palestine sandstone.	

DETAILED SECTIONS OF THE GLEN DEAN LIMESTONE.

The Glen Dean formation is less variable in its lithologic features than the Clore formation. Still, when closely compared, sections at different places show considerable differences in the proportion of limestone and shale and in the relative thicknesses of the beds of each. Unfortunately, reasonably complete exposures of the formation are not common. Besides, as this limestone is one of the easiest of the Chester series to recognize,

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it did not seem worth while to measure many sections. Accordingly only four detailed sections of the Glen Dean in western Kentucky were made by me in my first work on the stratigraphy of the area. Two of these, one at Smithland, the other at Carrsville, are in Livingston County, the others in Caldwell County.

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Section of the Glen Dean Limestone at Smithland.

	Ft.	In.
Quaternary conglomerate, mainly of chert, capping hill.		
Chester series.		
Glen Dean limestone, top not seen:		
Shaly limestone	1	2
Gray to blue impure limestone	1	4
Shaly limestone		8
Impure limestone		10
Shale		4
Grayish-blue, impure limestone	1	4
Yellowish, calcareous claystone	1	2
Rough, uneven-bedded, gray, impure limestone, with gastropods and Orthothetes	1	6
Light-gray to dark-gray, impure limestone, almost slaty near base; no fossils observed	5	8
(Perhaps a narrow interval.)		
Dark-gray or blue, soft, apparently unfossiliferous shale	13	0
Limestone, only partly exposed, about	6	0
Massive, blue, impure limestone, with *Zaphrentis spinulifera*	4	0
Ledge of gray, impure limestone	2	6
Soft, greenish shale with thin plates of highly fossiliferous limestone, Bryozoa chiefly	3	0
Yellowish, impure limestone, filled with brachiopods, *Spirifer increbescens*, *Composita trinuclea* or *Composita subquadrata*, and *Dielasma* sp.	2	0
Soft, green and blue, marly shale	2	6
Ledges of gray and blue, impure limestone with few good fossils but largely composed of comminuted remains	7	3
Soft, light-green shale	2	0
Limestone like second bed above	1	10
Soft, green shale, thickness not determined, about	5	0
(Probably a small interval.)		
Fine-grained, thin-bedded sandstone	5	0
Cherty limestone	2	2
Impure, in part shaly limestone	3	0
Crinoidal limestone	2	0
Dark-gray, arenaceous and cherty, fossiliferous limestone, including one layer of nearly pure crinoidal limestone, *Archimedes* cf. *swallovana*, *Fistulipora excellens*, *Meekopora* sp., and gasteropods	8	0
Concealed beds, probably mostly shale	7	0
Soft, green shale to base of exposure	3	0
Total exposure of Glen Dean limestone about	100	

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Though neither the top nor the base of the formation could be seen, this is one of the best and most extensive of the exposures of Glen Dean limestone seen by me in western Kentucky. Another notable feature is the large proportion of limestone contained in it. Most of the beds are fossiliferous, but specimens are good and readily procurable only from the beds mentioned as containing them. These furnished the large fauna listed on page 226.

Another good outcrop occurs in the banks of the Ohio and in the western edge of the town of Carrsville. The section at this place follows.

Section of the Glen Dean Limestone at Carrsville.

	Feet.
Tar Springs sandstone, the base only shown, the remainder cut off by a fault west of which higher Chester beds make the slope of a hill crowned by a thickness of 100 feet or more of Pennsylvanian sandstone.	
Glen Dean limestone:	
Bluish and greenish, calcareous shale interbedded with many thin plates of limestone, both highly fossiliferous, about	10
Soft, dark-blue, unfossiliferous shale including a few thin limestones that contain fossils, about	10
Bluish, fossiliferous, fairly pure limestone, the top ledge 2 feet or more in thickness but including some impure layers; the most fossiliferous bed of the section, the fauna a characteristic Glen Dean association	8
Grayish-blue, shelly and in part crinoidal limestone, with partings of shale from an inch to nearly a foot in thickness; fossils present but neither abundant nor good	12
Blue limestone, fossiliferous, shelly, exteriorly stained with rust, about	8
Roughly bedded, somewhat nodular, gray and blue, crinoidal limestone, with few other fossils, to base of exposure, about	6

Judging from sections observed across the Ohio in Pope and Hardin counties, Ill., the base of the Glen Dean limestone lies less than 30 feet, or possibly not over 15 feet beneath the base of the exposed part at Carrsville. Unfortunately the underlying Hardinsburg sandstone does not reach the surface in this immediate

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vicinity, being cut out by the Fairview fault which strikes the river at the landing. The quartzitic sandstone forming the small bluff just above the landing is an older formation—either the Cypress or the Aux Vases, the latter more probably.

Except that the formation is considerably reduced in thickness, the Glen Dean limestone is essentially the same in Crittenden County as at Smithland and Carrsville in Livingston County. In Caldwell County it continues to hold its general lithologic and faunal characteristics but, as shown by the following section, its thickness is even less than in Crittenden County.

Five to seven miles northwest of Princeton but mainly in the bluff and hill rising above Canadas Run, and between this stream and the house formerly occupied by Mr. J. K. Morse, is a fairly well exposed section beginning with the Hardinsburg sandstone and extending upward into the Palestine sandstone. The intervening formations—Glen Dean limestone, Tar Springs sandstone, and Menard limestone—are all thinner than in sections to the west and north. At the forks of the road half a mile north of the house, apparently still lower beds belonging to the Golconda formation are shown. All but the basal part of this section is repeated in the hill on the Fredonia and Wilson bridge road, about 1½ miles east of Ruth postoffice. At this place the section terminates above with a thickness of approximately 75 feet of Palestine sandstone. The section as made up from the mentioned outcrops is as follows:

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Upper Chester Section 5 to 8 Miles NNW. of Princeton.

	Feet.
Palestine sandstone, consisting of massive and thin-bedded, in part almost shaly beds with thickness of from 20 feet to over 75 feet capping the hills	75
Menard limestone:	
Gray crinoidal limestone, about	6
Grayish-blue, compact limestone, with rather few fossils, *Camarophoria explanata* perhaps the commonest, about	32
Total thickness of Menard limestone, about	38
Tar springs sandstone	15
Glen Dean limestone:	
Gray limestone, rather thick-bedded and with thin shale partings in upper 20 feet, more shaly and thinner-bedded in lower part; all ledges and most of the shales fossiliferous, *Spirifer increbescens* the only abundant fossil in the upper two-thirds, whereas the lower third is filled with the usual Bryozoa, *Productus*, and more or less imperfect crinoids and blastoids. The fossils listed as from Belleville Spring in Caldwell County came from the lower half of this bed	30
Soft, green shale	5
Shelly, impure, yellowish limestone full of fossils	10
Total thickness of Glen Dean limestone	45
Hardinsburg sandstone:	
Only the upper 4 or 5 feet of this formation is to be seen at the Morse locality. This consists of a platy argillaceous sandstone. Other incomplete exposures in the vicinity indicate a total thickness of approximately	40
Golconda formation:	
Impure, partly massive, partly shaly limestone, the upper two-thirds sparingly fossiliferous, the lower third containing a form of *Spirifer increbescens* in moderate abundance	11
Green shale above with much darker shale below, the latter with lenses and thin layers of satin spar; to base of exposure (in shaft)	28

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DETAILED SECTIONS OF THE GASPER OOLITE IN CALDWELL, CHRISTIAN AND CRITTENDEN COUNTIES.

What Mr. Charles Butts now proposes to call Gasper oolite is the formation that in 1905 was described by me under the name "Tribune" limestone. As previously explained, the term used by me has proved a misnomer and accordingly is now abandoned in favor of the new name.

In the years 1890-1905, when a part of my studies of the formations of the Chester series in the lower Ohio and Mississippi valleys was published, I held to the erroneous opinion that the formation more recently given the name Okaw limestone by Weller is the same as my "Tribune" (Gasper) limestone. At the same time I thought that the latter limestone increased in thickness in a northwesterly direction from eastern Caldwell, where it attains about 100 feet, to 150 feet or more in Hardin County, Ill., and finally to nearly 200 feet farther northwest. This mistaken view arose from the fact that in 1889, while studying the section in the vicinity of Chester, Ill., I found oolitic beds near the top of the main mass of the Okaw limestone; and these oolites contained a recurrent Spergen fauna that was unhesitatingly identified with the occurrence of a similar fauna in the upper part of the Gasper oolite in Caldwell County. At the time no later occurrence of this Spergen-like fauna than the one in the Gasper was known. Now, however, since the details of Chester stratigraphy are better understood, and the correlations between the formations in Randolph County, Ill., and those in western Kentucky are much clearer, we know not only that this fauna invaded the Mississippi Valley at least twice during the Okaw but also that the earlier Gasper invasion failed to reach Illinois at all.

The erroneous identification of the Gasper in the Okaw of the Randolph County area naturally led to other misconceptions. First, the reported presence of a large body of Gasper oolite at Tribune, in Crittenden County, which, however, has since proved to be the Menard and not Gasper, seemed so thoroughly in harmony

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with the requirements under the accepted view that I adopted the report with sufficient confidence to use the locality name Tribune for the formation. Next, it seemed altogether proper that the Gasper should be heavily developed on the Illinois side of the Ohio in Hardin County, but the outcrop of Chester limestone so identified at the Fairview mine doubtless is some other formation—probably the Ste. Genevieve.

In 1905* I mentioned six outcrops of the Gasper oolite without question and three others as more doubtful. Two of these have already been admitted as erroneous; and I may say at once that with the exception of the three places in Caldwell and Christian counties and the one in Crittenden County between Marion and View, all the others are either certainly or most probably in error. The fact is that the limestone facies of the Gasper does not extend northwestward beyond the Marion fault. Beyond this line it passes into the Ridenhower shale; and this represents only the upper part of the Gasper.

The last of the following three sections refers to a place in Crittenden County noted by me in 1889 but forgotten when the stratigraphy of the fluorspar veins was again investigated in 1902. The section here given is taken from the original notes which, as stated before, were not available when the published report on western Kentucky was written. The other two sections are the ones that supplied the fossils, the lithologic character and sequence of the beds, and their stratigraphic relations to other Chester formations on which my conceptions of the "Tribune," or as we now call it, the Gasper oolite, were originally founded. The first of these is on and near the Princeton to Hopkinsville road, the best exposures being in the first 2 miles after crossing the boundary between Caldwell and Christian counties. The second locality, as given in the old notebooks, is in a hill on the A. J. Lamb farm, about 3 miles east of Scottsburg. At the foot of the hill is a sulphur spring.

*Ulrich, E. O., and Smith, W. S. T. The lead, zinc and fluorspar deposits of western Kentucky. U. S. Geol. Survey Prof. Paper 36, pp. 59, 60, 1905.

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Section of the Gasper Oolite Near the Northwestern Border of Christian County.

	Feet.
Cypress sandstone, basal 6 to 25 feet shown at point where section was measured; full thickness of 100 feet or more in nearby hills to the north.	
Upper Gasper (or lower Cypress?):	
Ferruginous, calcareous, irregularly bedded sandstone, highly fossiliferous, containing the fauna listed on page 153	1–2
Soft, marly, unfossiliferous shale, purple above, green below	10
Brownish flaggy sandstone	6
Gasper oolite (typical):	
Gray, crinoidal limestone	3
Soft, marly, bluish shale	2
Irregularly bedded limestone	1
Limestone containing Pentremites	3
White and bluish ledges of oolite interbedded with a smaller proportion of crinoidal limestone. Oolitic beds in upper part filled with fossils, mostly of recurring Spergen forms. Associated with these are many distinctively Chester species (see list)	22
Greenish and light-colored shale and brecciated limestone, locally filled with fossils, mainly Bryozoa and Brachiopoda	1–3
White and bluish oolites, the lower ledges with large ova, the upper beds with relatively much smaller ova, all only very sparingly fossiliferous	20
Soft, calcareous, in part marly shale, with or without plates of limestone, both highly fossiliferous, making a conspicuous but unevenly distributed bed	0–7
Partly massive, partly shelly, bluish or gray, often crinoidal limestone, including some oolitic ledges, all more or less fossiliferous but, except a thin layer about 30 feet beneath the top which among other species contains an abundance of *Productus inflatus*, the fossils are not easily extractable. However, the weathered edges and residual clays often carry an abundant supply of silicified Pentremites and brachiopods; about	45
Total thickness of Gasper oolite	106 or 124
Aux Vases sandstone:	
Sandstone commonly thin and cross-bedded in the upper part, and relatively massive though sometimes flaggy in the lower third or half, holding a thickness in the area between the Princeton to Hopkinsville road and Cobb station or Cerulean Springs of	40–50
Ste. Genevieve limestone.	
Ohara member with the shale bed (faunal zone 3) at the top.	

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Section of the Gasper Oolite in Hills Near Railroad, About 3 Miles East of Scottsburg.

	Feet.
Cypress sandstone, perhaps including at the top some 50 feet of beds belonging to the Golconda formation (compare section taken in railroad cuts a mile or two east).	
More or less shaly sandstone, not well exposed, to top of hill, about	50
Limestone, with poor fossils, not clearly exposed	7–8
Sandstone, varying from more or less shaly or thin-bedded to massive ledges	120
Gasper oolite:	
Oolitic limestone, thickness not determined, say	5
Sandstone and probably shale, poorly exposed on slope covered with shaly and thin-bedded sandstone debris, about	25
Limestone, compact, rather impure, light-gray or drab-colored, full of small fossils representing many species	8
Sub-crystalline gray limestone with some ledges of oolitic limestone, with few good fossils	30
Greenish calcareous marly shale including thin plates of limestone, both very fossiliferous. Two outcrops of this bed in this vicinity provided nearly all of species listed as from the middle or shaly member of the Gasper	6
Dark-gray or bluish, mainly crinoidal and sub-oolitic limestone, with *Pentremites* of several species characteristic of the Gasper oolite and especially of this part of the formation	20
Covered space	(?10)
Massive, light-gray, crystalline limestone full of various kinds of shells and *Pentremites*	4
Soft shale, variegated, with very thin coal-like streaks	5
Total thickness of Gasper oolite, about	113
Aux Vases sandstone.	
Flaggy and cross-bedded sandstone, top only of formation exposed.	

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Section of Gasper Oolite in Crittenden County, About 2 Miles South of Crayneville.

	Feet.
Cypress sandstone (lower part only):	
Sandstone, thin-bedded, in part only	50+
Gasper oolite:	
Limestone, sparingly fossiliferous, 6 inches to	1
Sandstone	5
Oolitic limestone, with few fossils	4
Gray and bluish, thin-bedded, fossiliferous limestone interbedded with thin layers of calcareous shale	20
Massive crinoidal limestone	4
Total thickness of Gasper oolite	34
Aux Vases sandstone:	
Sandstone, of undetermined thickness, referred to this formation underlies the limestone.	

The relatively small thickness of the formation at this place suggests loss of beds from below by overlap and consequently that only the upper part is represented here by sediment. Further, the shaly character of much of the limestone foreshadows the lateral passage of the upper Gasper into the Ridenhower shale which occupies a corresponding position in the area to the northwest of the Marion fault in Crittenden and Livingston counties and thence across the Ohio in the southern counties of Illinois. The introduction of both these conditions—northwesterly overlap and lateral transition into a formation composed mostly of calcareous and arenaceous shale—is indicated already in southeastern Caldwell County and northwestern Christian County (1) by positive westward diminution in thickness of the lower member of the Gasper oolite, and (2) by the increasing development of shales and shaly sandstone in the upper part of the upper member of the formation.

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DETAILED SECTIONS OF THE STE. GENEVIEVE LIMESTONE IN WESTERN KENTUCKY.

GENERAL DISCUSSION.—The term Ste. Genevieve limestone was originally proposed by Shumard.* His reasons for separating it as a distinct formation from the St. Louis limestone, which generally underlies it, are not entirely clear at this time. However, his brief comments on the new formation indicate that he regarded the lithological characters as more nearly "analogous" to those of the Chester limestones than to those of the St. Louis. But, if we may judge from the contents of a note at the bottoms of the pages above cited, Shumard observed and based his conclusions mainly on differences in their respective fossils. Quoting from the note, he says:

"This group is well displayed on the Illinois side, a short distance above Prairie du Rocher, where it was first recognized by my colleague, Dr. J. G. Norwood, with whom I visited the locality last summer. During our visit, we collected from these beds an interesting suite of fossils, some of which prove to be new; others are species of the Kaskaskia limestone, but most of them are identical with forms that occur in the Second Archimedes or Warsaw limestone of Professor Hall's section. Among the species which have been recognized by us in these beds, we may mention *Rhynchonella trinuclea* (*Composita trinuclea*), *Rhynchonella wortheni* (*Pugnax wortheni*), *Spirifera hirsuta* (*Cliothyridina hirsuta*), *Retzia marcyi* (*Eumetria verneuiliana*?), *Spiriferina spinosa*. *Spirifer leidyi*, *Productus elegans* (*Diaphragmus montesanae*), *Productus biseriatus* (*Echinoconchus genevievensis*), *Murchisonia vermicula*, *Pentremites florealis* (*Pentremites princetonensis*), and one or more species of *Archimedes*."

Apparently Shumard had a fairly correct though perhaps incomplete conception of the fauna of the Ste. Genevieve limestone. Still, as pointed out by Worthen† on later pages of the volume in which the original reference to the Ste. Genevieve limestone is found, Shumard

*Shumard, B. F. St. Louis Acad. Sci. Trans., Vol. 1, p. 406, 1860; reprint in Missouri Geol. Survey Repts. for 1855-71, p. 293, 1873.

†Worthen, A. H. St. Louis Acad. Sci. Trans., Vol. 1, p. 696, 1860.

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mistakenly thought he recognized this fauna in a limestone, exposed on the Illinois shore below the mouth of Marys River, that is really a much younger bed, namely one near the top of the Okaw limestone. Worthen at the same time claimed that the outcrop above Prairie du Rocher referred to by Shumard is not even St. Louis but Warsaw limestone. And of the Ste. Genevieve limestone he says that it is "nothing but a part of the St. Louis limestone to which fossils of the Warsaw limestone have been erroneously referred." Of course Worthen did not then know that scarcely distinguishable facies of this Spergen or Warsaw fauna did invade the Mississippi Valley embayment not only in the age of the Ste. Genevieve but at least three times thereafter before the close of the Chesterian epoch; and as he believed in only the first or Warsaw existence of this fauna and did not know that *Diaphragmus elegans* accompanies all of its later, Chester, invasions of the Mississippi Valley, he naturally doubted Shumard's discovery of this characteristic Chester shell in association with "Warsaw limestone" fossils above Prairie du Rocher. But a form of *Diaphragmus* that Worthen himself would not have distinguished from *D. elegans* does occur sometimes abundantly in both the lower and the upper members of the Ste. Genevieve limestone in Kentucky; and so I see no valid reason to doubt Shumard's report of its presence in the same formation in the Mississippi Valley.

Several miles below the village of Prairie du Rocher, the base of the Aux Vases, or "Ferruginous" sandstone as it was formerly called, actually is in contact with the St. Louis limestone. But following the contact to the north, it presently opens to receive a somewhat gradually thickening wedge of Ste. Genevieve limestone. Both the top and base of the latter are in uneven contact with the overlying Aux Vases and the underlying St. Louis. Presumably, it is out of the thickened northerly extension of this wedge of St. Genevieve limestone that Shumard and Norwood collected the fauna mentioned and in part listed by the former.

Doubtless in consequence of Worthen's attempt to discredit the distinctness of the Ste. Genevieve lime-

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stone, the name given it by Shumard, and in fact the very existence of the formation was ignored by all writers of the geology of the Mississippi valley until 1894 when Keyes* revived the name and ranked the formation as the upper member or division of his St. Louis stage. Previous to this date, however, I had published preliminary results of my investigations in western Kentucky and applied the name Princeton limestone to what later proved to be the same formation.† After the identity of the two limestones had been established by comparison with Shumard's type locality 2 miles south of Ste. Genevieve, Mo., the name proposed by me was abandoned in favor of Shumard's older term.‡

At Ste. Genevieve a well-marked unconformity was discovered between the base of the Ste. Genevieve limestone and the top of the St. Louis limestone. The surface of the lower formation was not only beveled by erosion so that different layers came to the top, but showed evidence of subaerial decomposition, especially along joint planes that were subsequently filled with conglomerate of foreign material. In one place the enlarged joint plane could be seen to a depth of 5 feet. It varied in thickness from 2 to 6 inches; and the filling included pebbles of porphyry and other igneous rocks that must have been transported many miles. Photographs of the unconformity as developed in the Mississippi bluff 2 miles south of Ste. Genevieve, Mo., are shown in Plates G-1 and G-2.

At another place in Missouri about a mile southwest of St. Marys, Professor Weller led us to another excellent exposure of this contact. Here it was marked by a silicified conglomerate containing abundant specimens of Middle Devonian fossils together with a variety of igneous and other pebbles.

In the vicinity of Huntsville, Ala., the Ste. Genevieve part of the Monte Sana limestone locally rests on a considerable thickness of St. Louis limestone. In other places, as one beside the road going up Monte Sana, the

*Keyes, C. R. Missouri Geol. Survey, Vol. 4, pp. 30, 76, 1894.

†Ulrich, E. O. Geological and mineral resources of Crittenden County, Kentucky. "Crittenden Press," December, 1890. U. S. Geol. Survey Bull. 213, p. 207, 1903.

‡Ulrich, E. O. U. S. Geol. Survey Prof. Paper 36, pp. 39-53, 1905.

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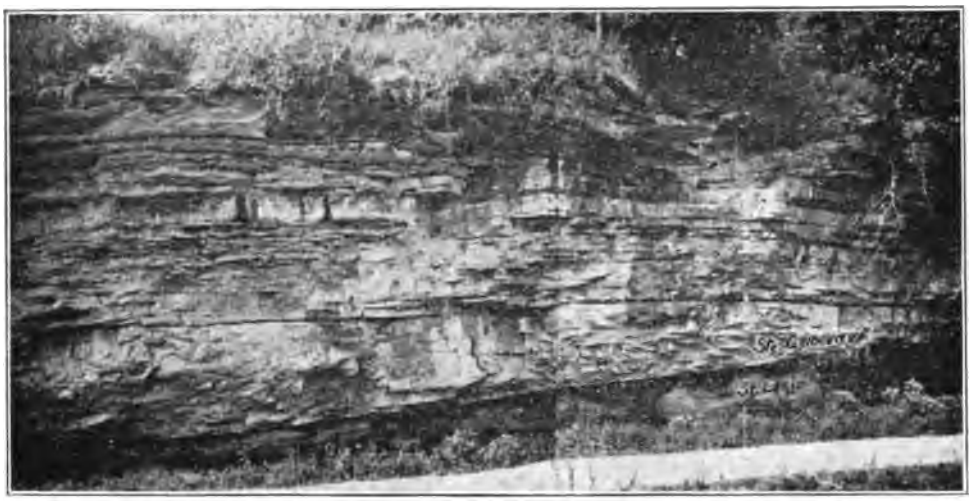

PLATE G-1.
Unconformable contact of St. Louis and Ste. Genevieve limestones at Ste. Genevieve, Mo.

PLATE G-2.
Unconformable contact of St. Louis and Ste. Genevieve limestones at Ste. Genevieve, Mo.

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whole of the St. Louis was removed except residual cherts and silicified masses of *Lithostrotion canadense* which make a basal conglomerate 1 to 5 feet thick on which the Ste. Genevieve was laid down.

Another excellent exposure of the base of the Ste. Genevieve is to be seen in an uncompleted railroad cut in the base of the bluff about 5 miles east of Jasper and 12 miles west of Chattanooga, Tenn. Here, as shown in Plates H-1 and H-2, the base of the Ste. Genevieve is very uneven, only remnants of the St. Louis limestone —0 to 7 feet in thickness—interposing between it and the eroded top of the Spergen limestone.

It is unfortunate that the actual contact between the Ste. Genevieve and St. Louis limestones has not been observed in western Kentucky. Wherever this boundary might reasonably be looked for in this region, the passage downward from the Ste. Genevieve to the St. Louis always proved to be covered by residual clays and soil. But the doubtful zone between the two is never wide. The soil left by the two formations is readily distinguishable, and when the section has passed only a few feet into the horizon of the St. Louis, the fact is at once conspicuously evidenced by great increase in quantity of the chert and by its rounded instead of platy form and usually dense instead of porous texture. So far, then, as the purposes of practical mapping are concerned, the difficulties in drawing this boundary are not extraordinary. Our dissatisfaction is warranted only to the extent of our inability to place a finger on the exact contact in an unweathered exposure.

But the examples cited from the widely separated localities in Missouri, Tennessee, and Alabama doubtless are sufficient proof of extensive and long-enduring land conditions between the close of the St. Louis submergence and the return of submergent conditions that prevailed thereafter with merely local oscillatory interruption to the close of the Ste. Genevieve. Indeed, this new submergence apparently continued without notable break throughout the southeastern half of the Chester area to the close of the Gasper and with it to the close of the Monte Sana stage.

For the sake of convenience and accuracy of refer-

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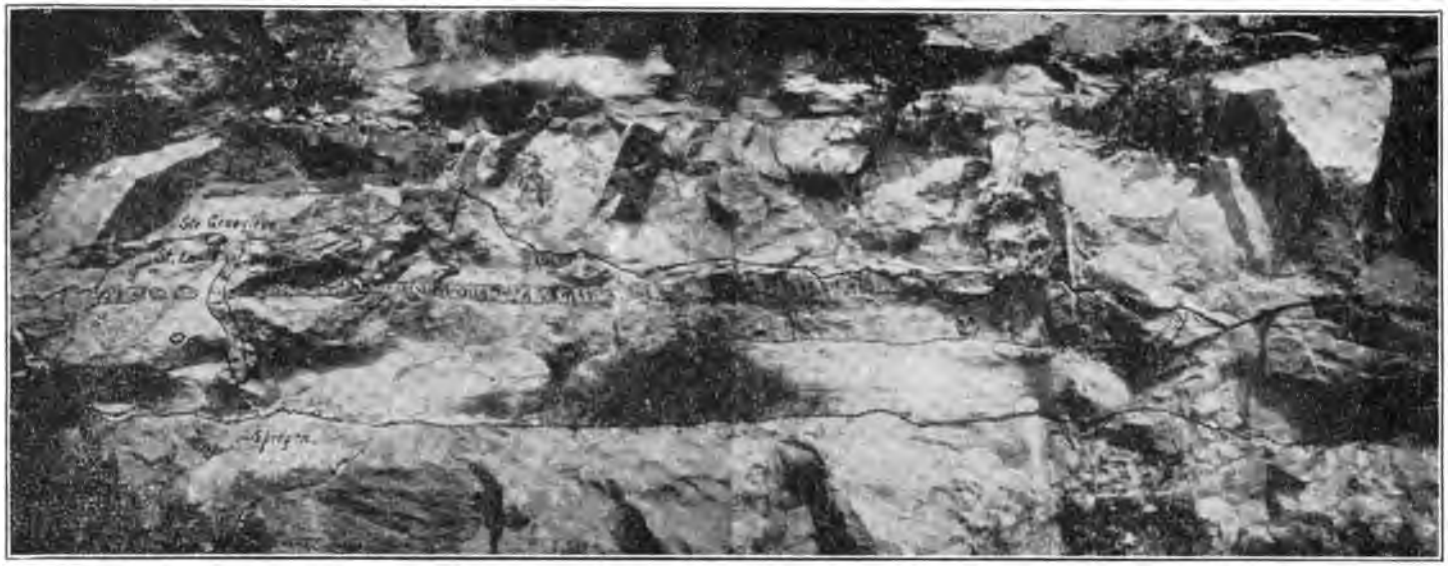

PLATE H-1.
Remnants of St. Louis limestone beneath the unconformable base of the St. Genevieve limestone. 5½ miles east of Jasper, Tenn.

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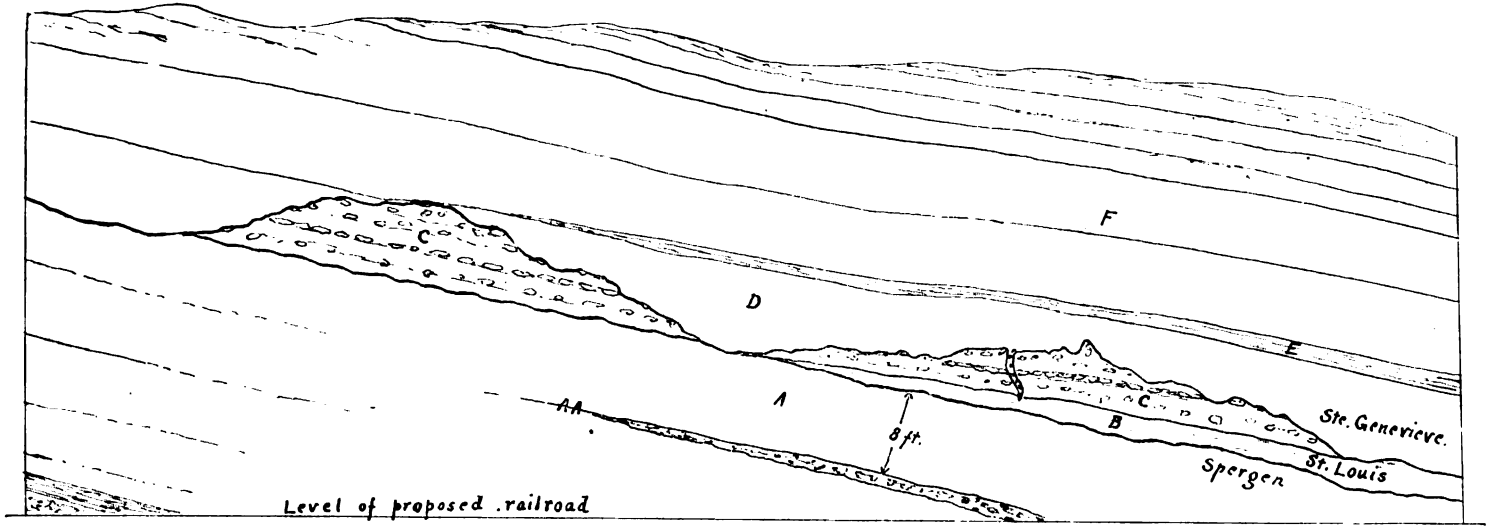
PLATE H-2



Sketch showing remnant of St. Louis limestone beneath unconformable base of Ste. Genevieve. Bluff 5½ miles East of Jasper, Tenn.

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ence the Ste. Genevieve limestone has been divided into three members, the Fredonia oolite below, the Rosiclare sandstone in the middle, and the Ohara limestone above. These members were described in considerable and, as I believed, sufficient detail in my previous report on western Kentucky, and I see no reason now that might cause me to regret anything I said in that report respecting the Ste. Genevieve limestone. However, as misunderstandings have arisen and doubt still prevails, further details seem required.

The first section measured by me in western Kentucky is the one shown in the southern slope of Cedar Hill, 2½ miles east of Princeton. That was in the fall of 1888. Small additions and corrections were made on four or five subsequent visits during the following two years. At the top of the hill is a low bluff formed by the basal 20 feet or so of the Aux Vases sandstone. Beneath this is the Ohara member, approximately 100 feet thick, and named from this place when about 12 years later the Ohara postoffice was established at the foot of the hill for the accommodation of the quarrying industry. The Ohara member is limited below by the Rosiclare sandstone, a persistent bed of calcareous sandstone here scarcely 2 feet thick. Beneath this sandstone the beds of the Fredonia member were continuously exposed to a depth of 60 feet, the lowest layers being in a sinkhole now probably covered with debris from the quarry.

When I first visited this place, and for some years after, quarrying operations were confined to the oolitic beds beneath the Rosiclare sandstone. The decomposing edges of these and other layers with which they were interbedded were thickly studded with good fossils; and the fossils were even more plentiful in gulleys excavated by rains in the residual clays between masses of undecomposed limestone and oolite. The Ohara exposure also, especially the beds above the conglomeratic layer, looked very different from what is to be seen now. The outcropping edges of the beds having been subjected to weathering influences for a long time were then really very productive collecting ground. All this has of course been greatly changed by the growth of the quarry.

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In order that the reader may gain a fair conception of the conditions as they were when the data were being collected on which the opinions previously published are based, I have decided to give here a transcript of my original notes on the locality.

Section at Cedar Hill, 2½ Miles East of Princeton
(Taken from measurements and notes made in 1888.)

	Feet.
Aux Vases sandstone:	
Massive, light-brown sandstone, 20 feet to top of exposure.	
Ste. Genevieve limestone.	
Ohara member:	
Limestone, gray or drab, of dense texture, impure, siliceous, with chert, the weathered surfaces showing coarsely silicified *Pentremites* and *Zaphrentis*	15
Sub-crystalline and semi-oolitic, bluish-gray limestone, with *Productus inflatus* and other fossils	4
Limestone, shelly-weathering and in part shaly, fine-grained, grayish, sparingly fossiliferous	8
Limestone, brownish or yellowish, argillaceous, fossiliferous, with *Diaphragmus montesanae*, *Orthotetes kaskaskiensis*, and Bryozoa of several species in moderate abundance	3
Marly shale, calcareous, fossiliferous, mainly Bryozoa, but containing also *Mesoblastus glaber*, *Pentremites princetonensis*, and some brachiopods (only 3 feet at top exposed in 1888, now known to reach)	6–7
Impure, argillaceous limestone, with shaly layers, containing many fossils, a *Buthotrepis* abundant and rather characteristic; fossils collected and noted in 1888 (perhaps belonging in part to the overlying shale) include *Zaphrentis spinulifera*, *Pentremites princetonensis*, two species of *Talarocrinus*, *Platycrinus huntsvillae*, *Platycrinus* sp., two species of *Fistulipora*, *Stenopora tuberculata*, *Batostomella* sp., *Fenestella tenax*, *Fenestella serratula*, *Polypora* cf. *cestriensis*, *Septopora* cf. *subquadrans*, *Sphragiopora parasitica*, *Orthotetes kaskaskiensis*, *Productus ovatus*, *Productus* sp., *Diaphragmus montesanae*, *Echinoconchus genevievensis*, *Spirifer* cf. *leidyi*, *Spirifer* cf. *bifurcata*, *Spiriferina* sp., *Spiriferina transversa*, *Composita trinuclea*, *Cliothyridina* cf. *sublamellosa*, *Diclasma* sp., *Girtyella* sp., *Euomphalus similis*, *Allerisma* sp., *Phillipsia* sp.	15
Limestone, impure, light-gray, weathering shelly, at top with Bryozoa, the remainder containing but few fossils	12

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	Feet.
Limestone, gray, subcrystalline, filled with *Diaphragmus montesanae* and *Productus* cf. *ovatus*—the *Productus* bed	1–2
Limestone, grayish, impure, compact, weathering shelly, with very few fossils	6
Conglomeratic limestone, the matrix sub-oolitic, grayish, under weather breaking up into pebble-like masses	3–4
Limestone, variable, commonly of light to dark shades of gray, mainly thin-bedded and somewhat shaly, especially toward the top; no fossils observed	23
Total thickness of Ohara member	99
Rosiclare sandstone member:	
Calcareous sandstone, greenish when fresh but weathering to a reddish-brown porous rock	2
Soft greenish marl, varying in thickness from a few inches to	2
Fredonia oolite member:	
Oolitic limestone, the ova rather small in upper part of bed but relatively large in lower half, the texture of the basal 4 feet being distinctly coarser than in the other beds. These lowest beds differ further in being largely composed of crinoidal remains and *Pentremites*	13
Oolitic limestone, compact in texture, brittle, with yellowish tints, especially toward the top; highly fossiliferous including *Cystelasma*, *Michelinia*, and many other fossils commonly found in the *Lithostrotion harmodites* zone	11
Shale, marly, green	1–2
Limestone, semi-oolitic, fine-grained, hard, conchoidally fracturing, mainly light-blue—*Lithostrotion harmodites* mainly in this bed	9
Shale, calcareous, fossiliferous	2
Limestone and shale, interbedded, more or less siliceous, the upper half light bluish-gray, the lower half commonly a darker gray. In fresh exposures the limestone appears massive but most of it weathers shelly. The purer layers contain fossils in abundance. On weathering these form porous cherty plates largely made up of silicified organic remains. At least two-thirds of the 50 or more species found in this cherty bed reappear in the upper Ohara	20
Coarse-grained oolite, nearly white, shown in wall of sinkhole	4
Thickness of Fredonia oolite member to base of exposure	61

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THICKNESS OF THE FREDONIA OOLITE MEMBER.—The base of the Ste. Genevieve limestone must lie at least 50 feet beneath the lowest bed seen in this section. This is inferred from the fact that the cherty zone, which is easily recognized by its lithologic and faunal characters throughout the southwestern part of Caldwell County and the southern part of Crittenden County, everywhere is underlain by 70 or more feet of mainly oolitic limestone before unquestionable evidence of the St. Louis limestone is to be seen. In fact the greater part of the highly productive Ste. Genevieve limestone farms in western Kentucky lies on these lower beds of the formation; and the St. Louis limestone areas beyond them are always sharply and conspicuously indicated by their profusely cherty characters and reduced productivity.

As I have already indicated, the full thickness of the Fredonia oolite member in Caldwell and Crittenden counties is known only approximately. Satisfactory outcrops of the lower beds of the member are uncommon and none of them is sufficiently characteristic to be recognized with certainty from place to place. However, we do know that the Fredonia exceeds 125 feet in thickness in Crittenden County, this amount of beds being shown in practically continuous exposures beneath the Rosiclare sandstone at two places, (1) at Bethel School, west of Marion, and (2) at View postoffice, in a southwesterly direction from Marion. Between the lowest bed in the second of these exposures and the top of a thick bed of chert in the bank of the creek 1 mile southwest of View—beyond which the land is clearly of the St. Louis type—the aneroid barometer indicated a further descent of 45 feet. Assuming horizontal strata across the intervening spaces gives a total thickness of at least 162 feet for the Fredonia member. As shown in a following section, a similar thickness is indicated in the area between Crider station and Fredonia in Caldwell County; and it can not be much less in the vicinity of Cobb station, near the southeastern border of this county, where the lower beds of this member stretch 2 miles southwestward from the outcrop of the upper cherty zone with *Productus inflatus* and *Pugnoides ottumwa* before real St. Louis limestone soil is found

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That a thickness of 160 to 170 feet is not unreasonable is indicated by Mr. Butts's measurements and estimates of exposures in Hardin County, Ill., at and above Rosiclare, where he determined the thickness of the Fredonia member as about 180 feet.

After another (1917) field season in southern Illinois, mainly in Hardin County, Mr. Butts has reached the tentative conclusion that a thick but hitherto unrecognized bed of cherty, fine-grained, bluish or dove colored limestone is locally intercalated in this region between the base of the Fredonia oolite and the top of the true—here darker, limestone of the St. Louis. This intervening bed is shown in the bluff in front of the hotel at Elizabethtown, Ill. Whether the bed extends into Kentucky to the south of Princeton is unknown but seems altogether improbable.

At, or rather, to the north of Cobb station the beds between the cherty zone and the base of the Rosiclare sandstone are only about 6 feet thick, hence much thinner than at Cedar Hill, 7 or 8 miles northwest, where, as given above, they reach 36 feet. The cherty bed, however, is about the same in thickness and character at the two places. The Rosiclare sandstone and the Ohara also are little if any inferior, the former being 2 feet and the latter at least 90 feet in the slope of the Aux Vases escarpment north of Cobb station. But only a few miles east of Cobb the Ohara is reduced to less than 70 feet by loss of the thick-bedded limestones that overlie the shale bed in the section at Cedar Hill.

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Section at and to the North of Cobb Station, in Caldwell County.

	Feet.
Aux Vases sandstone, 20 to 40 feet, at top of escarpment.	
Ste. Genevieve limestone.	
Ohara member:	
Cherty, gray limestone at the top, underlain by a shaly bed containing very fossiliferous plates of limestone and beneath this by firmer argillaceous limestone, about	60
Grayish limestone filled with *Diaphragmus montesanae* and *Productus* cf. *ovatus*, about	1
Limestones, variable in character, about	30
Total thickness of Ohara member	91
Rosiclare sandstone	2
Fredonia oolite member:	
Oolitic and subcrystalline limestone, very fossiliferous, massive	4–5
Fine-grained limestone, containing *Lithostrotion harmodites*	1–2
Light and dark gray, mainly thin-bedded limestones, interbedded with thinner layers of shale. Some of the limestones are crinoidal, others form thin plates of porous, fossiliferous chert on decomposition. Fossils: *Platycrinus huntsvillae*, *Pentremites princetoncnsis*, *Pentremites pulchellus*, *Rhipidomella dubia*, *Productus inflatus*, *Diaphragmus montesanae*, *Echinoconchus genevievensis*, *Spirifer leidyi*, *Reticularia setigera*, *Diclasma* cf. *formosum*, *Girtyella* sp., *Pugnoides ottumwa*, and many Bryozoa	22
Cellulose, fossiliferous chert, 3 to 15 inches, about	1
Limestone with nodular chert	1–2
Oolite, nearly white, massive, to base of exposure	8+

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Section of Fredonia Member of the Ste. Genevieve Limestone Between Crider and Bakers Station, Northwest of Princeton.

	Feet.
Aux Vases sandstone. The Ohara and Rosiclare members of the Ste. Genevieve limestone, and residual material indicating the upper 50 to 60 feet of the Fredonia member are to be seen in the rolling lands and escarpment to the north of the Princeton and Fredonia road. The following part of the section is made up of three disconnected exposures, the highest beds being shown along the wagon road southeast of the cemetery, the middle segment in Wilson's Cut near Charline, and the lower 43 feet in a gulley ending in a sinkhole near the Crider homestead. All these beds are thought to underlie the base of the section at Cedar Hill east of Princeton.	
Fredonia oolite member (beginning about 60 feet beneath the Rosiclare sandstone):	
Fine-grained oolite and dense, light-gray limestone	5
Oolite, very coarse, soft, white	8
Oolite, ova of moderate size, fossiliferous, fragmentary remains of *Platycrinus huntsvillae* and other crinoids very abundant, and *Pugnoides ottumwa* not uncommon, to base of exposure	4
(? Interval.)	
Top limestone in Wilson's Cut, compact, light-gray or drab, fossiliferous	3
Oolite, stratified, blue, hard and brittle, with occasional streaks of bluish speckled chert	6
Shale, greenish, sparingly fossiliferous at Charline (the same bed, apparently, in cut at Bakers Station is full of excellent fossils, especially Bryozoa of ordinary Chester types), nearly	2
Probable concealed interval of	5–10?
Oolitic conglomerate, abundantly fossiliferous (highest bed seen at Crider)	2
Limestone, crystalline, grayish and blue and layers of blue oolite	5
Oolite, white, much of it very fossiliferous and breaking up into plates under the weather; other layers have few fossils and make a fairly good building stone (apparently represents the most prolific of the zones containing the Fredonia facies of the Spergen fauna)	22
Limestone, grayish, impure, some layers slightly and very finely arenaceous	8
Good white oolite, with few fossils, to base of exposure in sinkhole	6+
	75–80+

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Section at View Postoffice, in Crittenden County.

	Feet.
Aux Vases sandstone, to top of hill	40
Ste. Genevieve limestone.	
Ohara member:	
This member is not well exposed here. Besides, at the place where the section was measured the vertical distance between the Rosiclare and the Aux Vases sandstone is only about 30 feet, though the cherty limestone that is usually present at the top in the thickest sections is present also here. As two or three small faults are known to pass through or near the line of the section, it is thought likely that at least 50 feet of the middle beds of the member have been cut out by these dislocations. If so, the thickness of the Ohara in this vicinity may be set down as approximately	80
Rosiclare sandstone, with characters as usual	5–6
Fredonia oolite member:	
Oolites varying from massive white ledges to light-bluish, thinner beds alternating with layers of bluish or gray crinoidal limestone and, especially in the lower part, some that are argillaceous or siliceous. The coral zone that is so commonly developed in this part of the section in Caldwell County has not been recognized either here or elsewhere in Crittenden County. About	70
Conspicuous layer of crinoidal limestone	4
Arenaceous limestone	3
Soft shales and thin plates of limestone, very fossiliferous, the fossils mainly Bryozoa and Brachiopoda	5
Limestone, very cherty	10
Oolite, laminar and very fossiliferous, alternating with more massive ledges of white oolite, to base of exposure	25
Concealed beds to first appearance of St. Louis limestone chert, about	45
Total thickness of Fredonia member, about	162
Total thickness of Ste. Genevieve limestone, about	248

Section of Ste. Genevieve Limestone Near Bethel School, 3 to 4 Miles West of Marion.

	Feet.
Aux Vases sandstone, capping hills, half or more of it commonly forming precipitous bluffs, about	80

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Ste. Genevieve limestone.

Ohara member:	Feet.
Rarely well exposed—talus covered—top variable, certain beds apparently present in some places and absent in others. Highest bed seen (near spring at fault 1 mile east of Bethel school) a greenish shale with poor fossils; above it soft reddish sandstone supposed to belong to the Aux Vases sandstone, beneath it a bed of purple, marly shale, in all about	10
Limestone (at same place), compact, containing *Lyropora* cf. *quincuncialis*, *Orthoceras* sp., and other fossils that are unknown in lower beds of the Ste. Genevieve limestone	2
Shale, green, marly	8
Shale and thin layers of limestone, more or less highly fossiliferous (faunal zone 3)	4–10
Massive, gray, impure limestone, in part becoming shelly under weather, no satisfactory exposure observed, about	40
Concealed (evidently limestone), about	10
Total thickness of Ohara member	50–80
Rosiclare sandstone member:	
Calcareous, laminated sandstone, grayish-green in fresh exposures but weathering to porous laminated masses or plates of reddish or yellowish sandstone	3
Fredonia oolite member:	
Limestone, compact, gray, the beds breaking vertically into rhomboidal blocks with smooth sides; no fossils observed	9–10
Limestone, variable, including one or two beds of good white oolite, the others being semioolitic, crinoidal, or subcrystalline and of various shades of gray; one layer yellowish-brown. Fossils occur mainly in occasional argillaceous layers or partings in which Fenestellidae in particular may be abundant	18
Limestone, the upper half fine-grained, light-gray, with a 2-foot layer of blue oolite below the middle and beneath this alternating layers of crinoidal and compact limestones. The lower third of the bed contains many fossils (especially *Platycrinus* and *Pentremites*) but they are not easily extractable	20
Limestone, siliceous, semi-crystalline, dark-blue, resonant, hard, difficult to work, formerly much used for fireblacks	15
Mainly oolitic limestone, most of it in thin beds, rather hard, light-blue, ova small; sparingly fossiliferous	42
Limestone, chiefly massive (layers 1 to 3 feet), compact, semi-oolitic, with very few good fossils, said to make good lime, to base of exposure	22
Total exposed thickness of Fredonia oolite member	127

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The beds of the Fredonia member in this section were measured in 1889 along the rising road going northwestward from Bethel school to Crittenden Springs, the Rosiclare sandstone being reached at a point half a mile or so from the school. The siliceous limestone probably corresponds to the lower part of the cherty bed near the base of the section at Cedar Hill, east of Princeton.

THE CHESTER SERIES IN TENNESSEE AND ALABAMA.

GENERAL DISCUSSION.—The formations of the Chester series east of Caldwell County, in Kentucky, are so fully described in the accompanying paper by Mr. Butts that even a generalized account of the section in this place would seem an unnecessary repetition. However, for the sake of completeness, the reader will find it an advantage to review the descriptions and particularly the columnar sections in Mr. Butts's paper because they bring out graphically many interesting and important variations in the distribution and character of the several formations.

Although variability in sequence and character of the beds is as much the rule on the south and east sides of the western coal field as on the western side, comparison of sections yet shows clearly that in all of the submergent stages of the Chester epoch the area embracing southern Illinois, southwestern Indiana, and Kentucky west of Louisville formed a single broad embayment of the sea. During the first or Ste. Genevieve stage this sea extended a long arm up the Mississippi Valley to southeastern Iowa, and in the Gasper stage a similar arm seems to have stretched from Indiana into Michigan, but in all other stages of the epoch the northern shore oscillated between the 39th and 40th parallels. At times, again, a secondary embayment was formed in the Mississippi Valley, between St. Louis and Cairo, in which different deposits were laid down from those forming at the same time in the greater, lower Ohio embayment to the southeast. This occurred particularly during the age of the Okaw limestone which is believed

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to be essentially contemporaneous with the Cypress sandstone. As the Okaw limestone is the most characteristic formation of this small bay, it might be distinguished as the Okaw bay.

As a rule, apparently, the Nashville dome formed either a large island or the expanded southern end of the Cincinnati peninsula. This land separated the western Kentucky part of the Mississippi Valley embayment from another large arm of the sea that stretched northeastward from the lower Mississippi across the Cumberland and Allegheny plateaus at times as far as southeastern Ohio and south-central Pennsylvania. The Nashville dome seems almost certainly to have been joined to the Cincinnati dome when the Golconda formation was being deposited in the lower Ohio embayment, because no beds of this age are known in eastern Kentucky and eastern Tennessee. They seem to be absent also in the Okaw bay, so that we may infer that the Golconda stage of the Chester sea was confined to the lower parts of the Ohio and Mississippi valleys. The two domes probably were similarly connected during the Chester stages following the Glen Dean. But during the Ste. Genevieve, Gasper, and Glen Dean stages it seems reasonably certain that the connecting land was submerged so that an open seaway passed between the Cincinnati and Nashville domes, making an island of the latter and establishing at the same time an efficient connection between the main western and eastern arms of the sea. These and other geographic peculiarities of the successive Chester submergences are indicated on the accompanying paleogeographic maps.

The Gasper and Glen Dean stages seem to have been the most extensive of the Chester submergences. Both extended far into Illinois, though probably not so far north in the Mississippi Valley as the Ste. Genevieve stage. Very characteristic upper Gasper and Glen Dean fossils are found also in the Paleozoic sinkholes in southwestern Missouri and adjacent parts of Arkansas and Oklahoma, so that it seems certain that the north Arkansas arm of the sea was occupied at these times. In the other direction they stretched across Illinois into Indiana, thence southeastward around the Cincinnati

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dome into the Allegheny region and in this far northward and southward, the Gasper is clearly recognized by its fossils in West Virginia, Ohio, and southern Pennsylvania in one direction, and in east Tennessee and northern Alabama in the other. The Glen Dean seems to have extended nearly as far northward in the Allegheny region, but is unknown in Ohio.

Considered in connection with preceding statements regarding the elimination of the sandstones from the Chester section in a southeasterly direction from western Kentucky, the foregoing brief discussion and accompanying maps of the paleogeography of the Chester epoch in eastern United States will assist the reader in understanding the differences in lithologic sequence that set the following sections in Tennessee and Alabama apart from those previously described. The Tennessee and Alabama sections were laid down in the Appalachian and Cumberland arm of the Chester sea, those already described were laid down in the Mississippi and lower Ohio basins.

A section of the Chester in southeastern Kentucky would be desirable in this connection. Unfortunately my notes on the stratigraphy in Pulaski County, made many years ago, have been mislaid or lost. However, relying on memory and collections of fossils made at various times during the three decades following 1879, when I first studied the section along the New Orleans and Texas Pacific Railroad between Somerset and Greenwood, the Chester section here begins with a thin development of the Ste. Genevieve limestone. This is followed by very similar Gasper limestone containing characteristic *Pentremites* and *Talarocrina*. Above this comes a thin sandstone—presumably representing the Cypress, but quite possibly a later bed—followed, between Tateville and Sloans Valley, by interbedded limestone and shales out of which Wetherby, Wachsmuth, and others gathered the excellent and prolific Glen Dean fauna that has made the locality at Sloans Valley known wherever collections of fossils are prized. The Glen Dean horizon is succeeded by a considerable thickness of beds consisting mainly of shales, with occasional layers of limestone and sandstone. These upper beds

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correspond in general to the Pennington shale which is typically developed and of great thickness in southwestern Virginia. In Pulaski County, Ky., it is followed by coal-bearing sandstones and shales belonging to the Pottsville series of the Pennsylvanian system.

The following three sections of Tennessee localities, referring particularly to thicknesses and lithologic characters of beds, are copied from Safford's "Geology of Tennessee," 1869, pages 352-358. The names of the fossils mentioned by Safford, when there seemed no doubt as to the species referred to, have been changed to designations now in use. Here and there also original comments and details are added, especially in the second or Bon Air section, concerning which notes recently made in this field by Mr. Charles Butts are before me. As Mr. Butts's notes indicate some differences in estimating the character and thickness of beds and also give details where Safford's description is more generalized, it has seemed desirable to reproduce both. The section at Huntsville, Ala., is based on notes made by the writer in 1903.

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Chester Section in Southern Part of Putnam County, Tenn.*

	Feet.
Pennsylvanian:	
Sandstone, on a high point south of the road. Thickness?	
Shales, a heavy bed, with clay iron-stones. This, with the (overlying) sandstones, was estimated to be	130
Sandstone, upper part thin-bedded or shaly	120
	250
Mississippian.	
Chester series ("Mountain limestone" of Safford):	
10. Blue limestone	4
9. Variegated shale, brown, gray, and green	12
8. Shale and marl, mostly gray, with some brown and green at the top; at intervals some thin layers harder than others	40
7. Argillaceous limestone, dull bluish-gray, breaking with conchoidal fracture; has cavities containing dolomite (probably corresponds to Nos. 5 and 6 in the Bon Air section)	27
6. Blue limestone, fossiliferous	22
5. Argillaceous limestone, resembling 7, above, but more compact and somewhat fossiliferous	20
4 Blue limestone	85
3. Shales	6
2. Sandstone, fine-grained, more or less flaggy (Cypress sandstone)	48
1. Blue limestone, fossiliferous (Monte Sana limestone)	168
Total thickness of Chester series	432
Meramec series.	
St. Louis limestone:	
2. Cherty limestone, limestone not seen, chert abundant on the surface	128
1. Limestone, impure, of waterlime aspect, lower part containing sparry blue layers; contains *Lithostrotion canadense*	75

In the Chester part of this section, No. 1 evidently represents the Monte Sana limestone, somewhat thinner than usual, possibly because of outlap westward. No. 2 is the sandstone that extends southward from Kentucky through Tennessee into Alabama. It is the only Chester

*Safford, J. M. Geology of Tennessee, p. 353, 1869.

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sandstone of any consequence in Tennessee and seems unquestionably an extension of the Cypress sandstone. Nos. 3, 4, and 5 and probably also 6 are referable to the Glen Dean limestone. No. 7 and possibly No. 6 are regarded as the Menard limestone of Kentucky and Illinois, whereas Nos. 8, 9, and 10 are thought to correspond to the Buffalo Wallow formation of west-central Kentucky.

Chester Section in White County, Tenn., Between Sparta and Bon Air.*

	Feet.
Pennsylvanian.	
2. Conglomerate, capping the mountain at Bon Air	90
1. Shales, with three or four thin seams of coal	102
	192
Mississippian.	
Chester series ("Mountain limestone"):	
8. Limestone, bluish, crinoidal, contains Archimedes sp. (*Archimedes swallovana* according to Safford but identification doubtful); some layers oolitic	40
7. Variegated shales and marls, green, brown, and gray; thin, harder layers at intervals; about the middle of the mass is a layer of shale full of *Composita subquadrata* and *Spirifer increbescens*	100
6. Shale or marl, with two or three beds of impure fossiliferous limestone and some cherty layers at top	15
5. Limestone, hard, blue, fossiliferous, weathering brown, contains cavities holding barite	7
4. Shale and limestone in alternating layers; upper part mostly shale, lower part mostly limestone; shales variegated, mostly greenish, some brown; limestone bluish-gray, fine-grained, argillaceous, breaking with conchoidal fracture, non-fossiliferous; at the base a cherty layer	63
3. Limestone, blue, fossiliferous, with occasionally a thin layer of shale; much of it oolitic; contains *Pentremites brevis* and *Pentremites pyramidatus*, *Agassizocrinus*, etc; has an argillaceous local layer in its middle part, about 5 feet thick, with a band of breccia marble above; at base, shale 5 or 6 feet	123
2. Sandstone, fine-grained and at some points flaggy, forms a bench around the mountain (Cypress sandstone)	40

*Safford, J. M. Geology of Tennessee, p. 355, 1869.

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		Feet.
1.	Limestone, in alternating, oolitic, sparry, crinoidal, and fine-grained argillaceous layers; two or three thin layers cherty; contains *Pentremites godoni* and *Pentremites pyriformis*, also *Agassizocrinus dactyliformis?*, *Zaphrentis spinulifera*, *Aspidodus crenulatus*, etc.; lower 50 feet of rock not seen	213
	Total thickness of Chester	601

Meramec series.

St. Louis limestone:

At base of the mountain; rocks mostly concealed, but surface covered with decomposing, fossiliferous, cherty masses, and among them specimens of *Lithostrotion canadense*, thickness,* as given in the section on Hickorynut Mountain, nearby 244

Chester Section Between Sparta and Bon Air, According to Notes by Mr. Charles Butts.

		Feet.
Pennsylvanian shale with coal at bottom (at Rockhouse)		70
Mississippian.		
Chester series:		
16.	Heavy-bedded limestone	22
15.	Concealed	28
14.	Purple and greenish soft shale or marl, with a few thin limestone layers	52
13.	Shale with five layers of limestone, the top layer 1 foot in thickness, the others varying from 2 to 6 inches, the lowest containing *Spirifer increbescens* and other fossils	44
12.	Limestone (probably same as No. 5 of Safford's section)	5
11.	Shale, with a 3-foot bed of shaly sandstone 10 feet above the base	40
10.	Limestone, thick-bedded, evenly fine-grained, light-gray, weathering buff or light-gray, breaks up into irregular conchoidal pieces; basal layer with chert and large *Spirifer increbescens*	30
9.	Limestone, of various kinds, thick-bedded, compact to medium-grained, blue, considerable of it oolitic, more of granular texture weathering crumbly and reddish on exposed surfaces; also some conglomeratic or brecciated layers, little or none of it yielding fossils in anything like abundance or perfection (Safford's No 3)	120

*In the Hickorynut Mountain section, Safford gives a thickness of 255 feet to Chester bed No. 1.

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		Feet.
8.	Sandstone, hard, flaggy (Safford's No. 2)	25
7.	Limestone, thickbedded, compact, blue, weathering smooth, containing some chert; *Productus inflatus* common	25
6.	Limestone, oolitic and granular, with *Agassizocrinus*	10
5.	Limestone, compact, brittle	5
4.	Limestone, mainly gray oolite, the upper layer containing brachial spines of *Hydreionocrinus?*	10
3.	Limestone, mainly light-gray oolite, resembling and probably the same as the oolite at Bowling Green, Ky.; fossils abundant, *Pentremites godoni*, *Pentremites pyriformis*, and other characteristic Gasper species of the genus; also *Agassizocrinus*	50
2.	Limestone, earthy, no fossils observed, spring flowing from its top (probably upper Ste. Genevieve)	6
1.	Limestone, mostly thick-bedded oolite; *Platycrinus huntsvillae* noted 25 feet above base	60
	Total thickness of Chester series	532
Meramec series.		
St. Louis limestone:		
4.	Limestone earthy, thick-bedded, possibly basal Ste. Genevieve	5
3.	Limestone, cherty, of usual St. Louis type	5
2.	Limestone, not exposed, surface thickly strewn with chert of types commonly found on areas of St. Louis limestone; about	60
1.	Limestone, thick-bedded, with *Lithostrotion proliferum:* to bed of Calf Killer Creek at bridge in Sparta	40

It will be observed that Mr. Butts's total thickness of the Chester at this place is short by 69 feet of the total given it by Safford. All but 7 feet of this difference is in the parts beneath the top of the sandstone (No. 2 of Safford's section), the sandstone in Mr. Butts's section being 25 feet against 40 feet in Safford's section whereas the Monte Sana limestone is 166 feet in the former and 213 feet in the latter. However, Safford says that the basal 50 feet of rock assigned by him to his limestone No. 1 was not seen. Deducting these concealed beds, the remainder is only a few feet under the aggregate thickness of the limestones noted in Mr.

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Butts's section between the sandstone and the top of the St. Louis.

The sandstone—No. 2 in Safford's section and No. 8 in Butts's section—is correlated with the Cypress sandstone. The overlying thick (120 feet or more) bed of limestone seems referable entirely to the Glen Dean formation. If so, then the Golconda formation is not represented here. Bed 10 in Mr. Butts's section appears to be of the Menard limestone; and bed 11 may correspond to the lower part of the Palestine sandstone. This would leave most of the succeeding 151 feet (comprised in beds 12 to 16) as probable correlates of the Clore formation.

Chester Section in Franklin County, Tenn., Along Railroad Between Cowan and Sewanee (After Safford, Geology of Tennessee, p. 356).

		Feet.
Pennsylvanian:		
4.	Sandstone, forms a bluff along the mountain	52
3.	Shale, with a thin seam of coal	14
2.	Sandstone, rather thin-bedded, at the base a ferruginus shaly layer containing nuts, calamites, etc.	25–30
1.	Local bed of sandy, ferruginous shale and a hard sandy, heavy ferruginous rock, below this bluish and brownish shale	12
		108
Mississippian.		
Chester series:		
21.	Limestone and shale, not well exposed; 3 feet of crinoidal limestone seen at the top; below this variegated brown and red shales, doubtless with some limestone	85
20.	Limestone, blue and light-blue, the latter oolitic	32
19.	Shale and limestone in alternating beds; shale greenish, bluish-gray, and brownish, and most abundant; limestone fine-grained, argillaceous, gives conchoidal fracture, breaks into angular pieces on exposure. (See No. 16 below). This division is much like 4 (Chester series) of the Bon Air section. The old Bowers road crosses the railroad track on this	70
18.	Limestone, rough, hard, rather thin-bedded, dark-gray, with sometimes a brownish tinge; has cavities lined with chalcedonic quartz and some filled with gypsum; includes a few layers of shale	25

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		Feet.
17.	Limestone, blue, fossiliferous, some of it oolitic; *Pentremites pyramidatus?*, *Spirifer increbescens*, etc.	21
16.	Limestone and shale, like 19, above; the most of it thick-bedded limestone; decomposes easily like that referred to above, both forming glady places along the sides of the mountain	35
15.	Limestone, heavy-bedded; lower part abounds in cavities, some filled with gypsum	55
14.	Limestone, dove-colored, argillaceous, weathers in rough layers, contains cavities lined with crystals; 8 feet of the middle part rather even-bedded, with a line of small chert nodules in one layer	28
13.	Limestone, mostly oolitic, heavy-bedded and light-bluish, fossiliferous; near the base *Archimedes*, *Pentremites*, etc.	50
12.	Shales and limestone alternating, above argillaceous limestone, weathering to shale, containing cavities lined with crystals of quartz and of calcite (8 feet); below this blue, compact, fossiliferous limestone (6 feet); then a limestone weathering to dirty drab (4 feet), argillaceous, dove-colored limestone (3 feet), blue, fossiliferous limestone (3 feet)	26
11.	Shale, greenish and bluish	12
10.	Sandstone, fine-grained, micaceous and calcareous	8
9.	Shale; contains a few layers of limestone, one in its middle part 3 feet thick and oolitic; fossiliferous	31
8.	Limestone, thick-bedded, lower part dark-blue and sparry; upper light bluish-gray and oolitic; at top a foot or two of thin limestones and shales abounding in *Archimedes*, the whole mass very fossiliferous; (*Productus inflatus*, *Diaphragmus montesanae*, *Echinoconchus genevievensis?*, *Martinia* sp., etc.)	13
7.	Greenish shale, with a bed of limestone 3 feet thick 4 feet from the bottom; mass fossiliferous	27
6.	Limestone, mostly dove-colored, some layers compact without fossils, others sparry, with them; at top is a layer of bluish-gray, oolitic limestone, 5 feet thick, which forms the ceiling of the Nashville, Chattanooga & St. Louis Railway tunnel as its western end; a large specifically undetermined *Pentremites* in the lower part	32
5.	Limestone, knotty and argillaceous, weathers into knotty lumps and shale; lower layers contain Archimedes; also *Spirifer leidyi*, *Spiriferina spinosa*,	

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		Feet.
	Composita trinuclea, and *Talarocrinus* aff. *sexlobatus**	9
4.	Limestone, mostly thick-bedded, much of it oolitic and light-colored, some crinoidal, other beds compact and argillaceous; *Pentremites godoni*, *Pentremites planus*, *Pentremites pyriformis*, etc.	70
3.	Limestone, blue, thin-bedded, with cherty seams; contains *Archimedes* and *Pentremites* cf. *princetonensis*	8
2.	Limestone, beautiful bed of gray limestone, with but a trace of blue	20
1.	Limestone, alternating beds of gray, oolitic, and dove-colored or blue argillaceous limestone	57
	Total thickness of Chester series	714
	Meramec series.	
	St. Louis limestone:	
	Cherty limestone, very fossiliferous, down to the creek at Cowan, about	110

CORRELATIONS WITH SECTIONS IN KENTUCKY.—In this excellent section beds 1 to 3 of the Chester series are correlated with the Ste. Genevieve limestone of Kentucky and the Mississippi Valley. Possibly they represent only the Fredonia member of the formation; but, so far as the data in hand justify an opinion, it seems just as reasonable to say that they are entirely of Ohara age. However, probably neither of these views would be quite true. My belief is that these 85 feet of basal Chester limestone include representatives of both the Fredonia and the Ohara. But where the line between them is to be drawn, or whether the top bed (No. 3) corresponds to an upper or a low zone of the Ohara at its type locality, are questions that can not be answered at present. The same is to be said also of beds 1 and 2 in Butts's section near Sparta.

There is much less chance for question when it comes to the Gasper oolite equivalents in these two sections. In fact the fossils as well as the lithology of the

*Many thousands of specimens of Pentremites, representing at least a dozen species, all of them characteristic of the Gasper limestone horizon in this and adjoining States, have been collected from exposures of apparently this and the overlying bed in the vicinity of Cowan. The Pentremites are associated with several species of crinoids and three or four species of brachiopods.

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beds between the top of the Ste. Genevieve part of the Monte Sana limestone and the base of the overlying sandstone indicate Gasper, and only Gasper. Further, all lines of evidence tend to the conclusion that the sandstone represents the Cypress sandstone in Kentucky and southern Illinois.

Considering details, No. 4 of the Cowan section should correlate with the lower limestone of the Gasper in the sections of Caldwell, Christian, and Warren counties, Ky. The fossils, especially the Pentremites, are practically identical in kinds; and the rocks themselves are hardly less in accord. Then, No. 5 may very well correspond to the middle shale member of the Gasper in Kentucky; and the succeeding Nos. 6 to 9, inclusive, despite their unusually great aggregate thickness of 103 feet, to the upper member. In Kentucky the upper part of the Gasper, especially in the thickest sections, is often shaly. Indeed, in eastern Caldwell and northwestern Christian counties it includes even sandstone. In Breckinridge and adjoining counties where this upper sandstone is wanting and probably represented by limestone, the latter commonly contains a fauna marked by *Productus inflatus* and *Martinia* sp. A zone apparently corresponding to this is found also in the Cowan section (bed No. 8). Over this is the shaly bed 9.

Bed 9 includes near its middle an oolitic limestone. A similar limestone is found with shale or sandstone above and beneath it in the two sections given, the first being in the northwestern corner of Christian County, the other 8 or 10 miles to the northwest in Caldwell County. Possibly these three limestones are essentially comparable. At all events these Kentucky sections of the Gasper oolite seem in reasonably close accord with the beds in the Cowan section here assigned to the same age and formation.

The beds above the Cypress sandstone, which is the same sandstone to which Butts* has restricted the term Hartselle, previously employed in a broader and looser sense by McCalley,† are not so easily correlated with

*Butts, Charles. U. S. Geol. Survey Atlas, Birmingham folio (No. 175), p. 7, 1910.

†McCalley, Henry, Alabama Geol. Survey Rept. on valley regions, pt. 2, pp. 183-185, 1897.

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the formations of the Birdsville recognized in western Kentucky and southern Illinois. The difficulties arise primarily from the fact that the sandstones which punctuate the Birdsville section in the latter areas are wanting in the Tennessee sections and, as we shall see presently, also in the Alabama section. In these southern States, except the Appalachian Valley areas, the Birdsville part of the Chester series consists almost entirely of limestone. In the Appalachian Valley, especially in northeastern Alabama, northwestern Georgia, and southwestern Virginia, the upper part generally and in places also the middle and lower parts of the Birdsville consist largely or perhaps wholly of shale and sandstone facies to which various names, notably Pennington shale, Floyd shale, Oxmoor sandstone, and Parkwood formation, have been more or less consistently applied. The limestone facies which prevail to the west of the Appalachian Valley proper have been referred to the "Bangor," "Newman," and "Greenbrier" limestones, but the significance of these names as applied in different places varies so greatly that they have no definite status in systematic stratigraphy. Unless they are redefined and restricted to one or another of the several diastrophically limited units commonly combined under these names, their further employment is defensible only on the ground of broad convenience in designating contiguous beds of similar lithologic character.

The sandstones—Hardinsburg, Tar Springs, and Palestine—of the section in western Kentucky, most probably are represented in these Tennessee sections by limestone. It is believed also that closer study of the southern sections than has yet been given them will reveal physical evidence of interruption of sedimentation at horizons corresponding to the sandstones in the Kentucky sections. At present, however, it is not possible to say just where these probable breaks occur. The best I can do now is to pick out zones that in my opinion fall into the intervals covered by formation names in Kentucky and Illinois.

In the Cowan section given above beds 11 and 12, comprising 38 feet of shale and limestone, are thought to fall within the limits of the Golconda formation.

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This opinion is based partly on stratigraphic considerations but mainly on a collection of fossils procured from apparently the same position 8 miles north of Chattanooga. Besides, supposedly characteristic Golconda fossils occur also to the southwest of Cowan in Lawrence County, Ala., so that it seems altogether proper that this formation should be represented in the Cowan section in which, moreover, the Chester series is thicker than in the preceding Tennessee sections.

Bed 13 in the Cowan section is doubtful. Possibly it represents the Hardinsburg sandstone. Beds 14, 15, 16, and 17, however, I correlate with the Glen Dean formation. Bed 18, again, is doubtful, but 19 falls either wholly or partly into the Menard limestone. Finally, beds 20 and 21 represent the Buffalo Wallow formation of south central Kentucky and either or both of the essentially corresponding Palestine and Clore formations in western Kentucky and Illinois.

Section of Monte Sana, Near Huntsville, Ala.

	Feet.
Pennsylvanian.	
Ferruginous sandstone, at top, about	50–70
Dark shale, irregularly bedded, with impure coal, about	5–20
Mississippian.	
Chester series.	
Birdsville group:	
21. Light bluish-gray limestone, containing *Pentremites* aff. *cherokeeus*, one or two species of *Archimedes* with other Bryozoa, and, according to Worthen, fish teeth referable to *Aspidodus crenulatus*, approximately	45
20. Gray limestone, some of it cherty, interbedded with calcareous shale, fossiliferous; *Spirifer increbescens*, *Composita subquadrata*, and other fossils, with Bryozoa uncommon, to talus covered space	20
19. In part limestone, mostly concealed, surface covered with talus mainly of sandstone from overlying Pennsylvanian; about	25
18 Shale interbedded with argillaceous limestone, the latter with plates of chert	18
17. Mostly unfossiliferous shale, with a calcareous sandstone full of ordinary Birdsville fossils, especially Bryozoa, at the top	17

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		Feet.
16.	Limestone, massive, argillaceous, with crystalline specks representing crinoidal debris	10
15.	Very argillaceous, yellowish limestone grading upward into clay shale	28
14.	Limestone, compact, mostly dark-gray, with few fossils	48
13.	Limestone, compact, gray, with fossils; at top a layer with spines and plates of *Archeocidaris*, the remainder with *Camarophoria explanata*, a large species of *Bellerophon*, and other fossils	25
12.	Limestone, very finely oolitic, massive, with large *Bellerophon* in basal part	12
11.	Apparently mostly limestone, not fully exposed; contains large masses of a loosely laminated *Stromatocerium* like organism	34
10.	Limestone, gray, argillaceous, some of it laminated, contains *Pentremites johsi* and large *Bellerophon*	21
9.	Limestone, argillaceous, poorly exposed	20
8.	Limestone, argillaceous, most of it yellow	20
7.	Limestone, in moderately heavy beds, mostly gray, some layers compact, others more or less crystalline; toward the base with thick shale partings; contains fossils but these are not easily procurable, among them a *Pentremites* related to *Pentremites cervinus*	70–80
6.	Sandstone, brownish, in thin and relatively thick layers; according to Worthen contains fossil plants	10–15
Monte Sana limestone.		
Gasper oolite.		
5.	Shales and marls, calcareous, with some limestone at top, very fossiliferous; 6 brachiopods, among them a *Chonetes* and *Martinia*, 20 to 30 species of Bryozoa, including *Coeloconus granosus*, *Cystodictya*, *Meekopora*, and 5 or 6 species of *Archimedes*, a low-based *Agassizocrinus*, a small *Orthoceras*, and *Zaphrentis spinulifera*	12-15
4.	Limestone, heavy-bedded, mostly oolitic	35
3.	Shale and shaly limestone, with abundant silicified and unsilicified *Pentremites*	5
2	Limestone, crinoidal and oolitic, certain layers very fossiliferous; *Pentremites godoni*, *Pentremites planus*, *Pentremites pyriformis*, and many species of crinoids, most of them, as is true also	

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	Feet.
of the *Pentremites*, identical with species found in the Renault formation in Illinois	45
Ste. Genevieve limestone:	
1. Limestone, mostly oolitic but with some layers sub-crystalline or crinoidal locally with a shaly bed in the upper part that has supplied thousands of specimens of *Platycrinus huntsvillae* and other crinoids; these are associated with many other fossils commonly found in the Ste. Genevieve limestone and particularly in the middle and upper zones of the Ohara member; at least two zones below the middle contain the Fredonia facies of the recurrent Spergen fauna; no clearly marked break at the top; as determined in the field the boundary was drawn at the top of a bed containing *Rhipidomella* cf. *dubia*	70
Total thickness of Chester series	613
Unconformity.	
Meramec series.	
St. Louis limestone:	
Uneven bed of agglomerated chert, evidently residual St. Louis chert recemented and silicified after a long period of subaerial decomposition and erosion	1–3
Limestone, dark-gray, with nodules of chert and *Lithostrotion canadense;* apparently absent in places where pre-Chester erosion cut through to the underlying Spergen limestone	0–10
Spergen and Warsaw limestones:	
Limestone, mostly massive, white and gray, most of the ledges oolitic, other crinoidal or subcrystalline, others compact and slightly argillaceous; to top of underlying Fort Payne chert at least	150

McCalley* describes two "Hartselle" sandstones in the area to the south and east of Huntsville. The upper of these is the one seen in the slope of Monte Sana (Chester bed 6 of the above section) and, according to Mr. Butts, at Hartselle.† The lower sandstone does not occur in the Monte Sana section; and I have not seen it elsewhere. However, as I have never visited the localities in which it is said to occur, I have no rea-

*McCalley, Henry. Alabama Geol. Survey Rept. on valley regions, pt. 2, pp. 183-185, 1897.

†In recent publications by the U. S. Geological Survey, Mr. Charles Butts restricts the name Hartselle sandstone to this upper bed.

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son to doubt McCalley's observations. As described by him, this lower sandstone appears to come in just over the cherty limestone with *Lithostrotion canadense* at Trianna on Tennessee River, not far from Decatur; in other words, between the St. Louis and the Ste. Genevieve limestones. A sandstone in this position would be a welcome addition to the other physical criteria indicating an important break between the Meramec and Chester series as defined by me. Still, pending further investigation, we must not ignore the possibility that it represents the Rosiclare sandstone member of the Ste. Genevieve as developed in western Kentucky and Illinois. The matter is worthy of close investigation, for even if the sandstone proves to be the Rosiclare, it would yet have an important and probably conclusive bearing on the supposed Ohara age of the main *Platycrinus huntsvillae* zone in the upland sections immediately to the east and south of Huntsville.

That bed 1 of the Chester part of the Monte Sana section corresponds to the Ste. Genevieve limestone of western Kentucky and Illinois I take to be established beyond all possibility of doubt; and I am no less confident regarding the correlation of beds 2 and 5, inclusive, with the Gasper oolite. Further, if fossils are worth anything at all in stratigraphic correlation, then bed 2 is of the age of the Renault formation in the Mississippi Valley, and bed 5, and probably also beds 3 and 4, of the Paint Creek formation.

Concerning the Birdsville part of the section, there is some doubt as to the presence of beds corresponding to the Golconda formation. Bed 7 may be of this age, but decisive fossil evidence is not at hand. Bed 10, however, is certainly of the Glen Dean limestone, and probably well up in the formation. Farther up, beds 13 and 14 remind strongly of the Menard limestone. Finally, beds 17 to 21 indicate the Clore formation and perhaps also the Palestine sandstone.

Considered from the standpoint of practical and at the same time systematic mapping, the Chester series in east central Tennessee and north central Alabama is divisible into only two definitely and uniformly delimitable limestone units. These are separated by the Cy-

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press, or Hartselle, sandstone, which may be viewed as a third unit, or better, as the basal member of the Birdsville limestone. To the other—lower—formation I applied the term Monte Sana limestone.*

*Ulrich, E. O. Revision of the Paleozoic systems. Bull. Geol. Soc. America, Vol. 22.

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PART 3. PALEONTOLOGY OF THE CHESTER SERIES.

FAUNAS OF THE LOWER CHESTER OR MONTE SANA GROUP.

STE. GENEVIEVE LIMESTONE FAUNAS.

FAUNAS OF THE FREDONIA OOLITE MEMBER.—Many layers in this member of the Ste. Genevieve limestone are fossiliferous but in most of them the fossils are imperfectly preserved or too difficult to extract. Still, a few of the fine-grained non-oolitic limestones always supply some reasonably good specimens, and in places where the residual clays have been recently exposed to the weather, fossils, that in such cases are commonly silicified, may be procured in considerable abundance and variety. The cherty bed about 40 feet beneath the top of the member as developed in Caldwell County is often filled with organic remains. The *Lithostrotion harmodites* bed contains good fossils of other types besides the characteristic corals. The oolitic beds, though as a rule the least promising, are in places filled with excellent fossils. Indeed, more than half of the known fauna of the member was procured from oolitic layers. The recurrent Spergen forms, though far from being confined to such layers, are mainly found in them. Still, many of the small molluscan species have been observed only in the oolites.

As previously stated, three zones in the upper part of the member are distinguishable by faunal peculiarities. The differences occur mainly among the corals and Pelmatozoa, with less striking differentiation among the Bryozoa and brachiopods. The molluscan faunas of the oolitic beds, on the other hand, show little difference whether found near the top or the bottom of the member. The differences observed in comparing lists from several beds in the same section seem due to chance in collecting or in distribution rather than to absence from

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the sea at such times. This conclusion is indicated by the fact that species found in a low bed and not in a higher one at the same place are likely to be found in correspondingly high zones in a nearby locality. Besides, nine-tenths of them have not only very close and often indistinguishable progenitors in the Spergen fauna, but equally consistent descendants in the oolites of the Gasper oolite and Okaw limestone. Because of their persistence, which makes their testimony pull upward in the geological scale at least as strongly as downward, these Spergen types can play no decisive part in determining the Chester or Meramec age of the Ste. Genevieve limestone. The purely paleontological answer to this question must depend mainly if not entirely on the other classes of fossils.

In Caldwell County the upper 30 to 50 feet of the Fredonia generally contains a number of conspicuous fossils that up to the present have not been found either above or beneath this zone. As the more striking and abundant of these are corals, it seems desirable to name the zone for one of them. The following list includes those most commonly met with in Caldwell and Crittenden counties. Those supposed to be confined to the bed are starred.

Incomplete List of Fossils of the Lithostrotion Harmodites Zone, Including Most of the Characteristic Species.

Zaphrentis pellaensis.
Zaphrentis spinulosa.
*Zaphrentis radicosa n. sp.
*Menophyllum excavatum n. sp.
*Menophyllum haimeanum n. sp.
*Menophyllum princetonense n. sp.
*Cystelasma quinqueseptatum.
*Lithostrotion harmodites.
*Michelinia subramosa.
*Michelinia princetonensis.
Mesoblastus glaber.
Rhipidomella dubia var.
Productus inflatus var.
Productus arkansanus.
Diaphragmus montesanae.
Streptorhynchus cf. ulrichi.
Spiriferina (2 new species).

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Associated with the listed species are many that range up from lower horizons, and others that pass upward to various horizons in the Ohara member or to yet higher positions in the Chester series.

The following list gives a fair idea of the Fredonia fauna as a whole. It is made up of species found in 1888 and 1889 at several outcrops at or near Princeton in Caldwell County, and at View (6 miles south of Marion) in Crittenden County. More than 80 per cent. of the total number was found in both localities. An effort—doubtless not entirely successful—has been made to bring the determinations up to date in matter of nomenclature. Of greater importance is the fact that in every instance, referring not only to the Fredonia faunas but also to all the higher faunas listed on succeeding pages, the determinations have been verified for the present work. It is, therefore, to be understood that when the same name is used in two or more lists, the specimens of the several occurrences proved practically indistinguishable either as species or well-marked varieties. Perhaps it is unnecessary to add that the distinctions were drawn in all cases with the highest degree of precision of which I am capable.

Earlier and later occurrences of the Fredonia species are indicated by appropriate signs. Thus, a cross (x) in the first column indicates that the particular species is represented in some bed or beds of the Ohara member *above* the conglomeratic layer by specimens that I could not distinguish specifically or varietally from the Fredonia specimens. On the other hand, when the Ohara specimens are distinguishable and still the nearest relatives of the concerned Fredonia species known, the fact is indicated by the letter "R." Similarly, practical identity with or nearest relation to older Warsaw, Spergen, or St. Louis fossils is indicated by the same signs in the second column; and likewise in the third column when such relatives have been found in the younger fauna of the Gasper oolite. Finally, when the relations of the Fredonia fossils to their older and younger representatives have not seemed decisively in favor of either, the doubt is indicated by a zero (o) in both columns.

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Composite List of Fossils in the Fredonia Oolite.

	Ohara relatives	Meramec relatives	Gasper relatives
1. Zaphrentis pellaensis	X		X
2. Zaphrentis spinulosa	X		X
3. Zaphrentis radicosa n. sp.		R	
4. Menophyllum excavatum n. sp.		?	
5. Menophyllum haimeanum n. sp.		R	
6. Menophyllum princetonense n. sp.		?	
7. Lithostrotion harmodites			
8. Cystelasma quinqueseptatum		R	
9. Cystelasma rugosum		R	
10. Michelinia subramosa		O	O
11. Michelinia princetonensis		O	O
12. Michelinia n. sp. ? (More massive and with larger cells than preceding. Most like a species in the Golconda shale.)			R
13. Palaeacis aff. cuneiformis		O	O
14. Cladochonus sp.		R	
15. Syringopora? aff. monroensis		O	O
16. Pentremites pulchellus n. sp.	X		R
17. Pentremites pulchellus, slender variety	X		
18. Pentremites princetonensis n. sp.	X		R
19. Pentremites princetonensis, var.	X		
20. Pentremites tuscumbiae n. sp.	X		R
21. Pentremites pinguis n. sp.	X		R
22. Mesoblastus glaber	X	O	O
23. Platycrinus huntsvillae	X		
24. Platycrinus penicillus			
25. Batocrinus aff. euconus	X	R	
26. Dizygocrinus superstes n. sp.	?		
27. Dizygocrinus superstes var.	X		
28. Dizygocrinus unionensis (Wachsmuth and Springer, not Worthen)	?		
29. Taxocrinus semiovatus			
30. Zeacrinus intermedius	R		R
31. Ortonia sp.	X		
32. Fistulipora cf. spergenensis	X	R	
33-35. Fistulipora (3 species)	X		R
36. Stenopora tuberculata	X	X	X
37. Anisotrypa fistulosa	X		R
38. Rhombopora parsimilis?	X		X

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Composite List of Fossils in the Fredonia Oolite—Continued.

	Ohara relatives	Meramec relatives	Gasper relatives
39. Cystodictya aff. pustulosa	X		X
40. Septopora cf. cestriensis	X		X
41. Fenestella serratula	X	X	X
42. Fenestella tenax	X	X	X
43. Fenestella cf. cestriensis	X		R
44. Fenestella cf. elevatipora	X		R
45-47. Polypora (3 undet. species)	R		R
48. Archimedes cf. meekanus	X		R
49. Thamniscus furcillatus			X
50. Rhipidomella dubia var.	X	R	R
51. Orthothetes (small, near Chester species)	X		R
52. Streptorhynchus cf. ulrichi		O	O
53. Streptorhynchus sp.	X		
54. Productus pileiformis	X		R
55. Productus arkansanus			X
56. Productus inflatus var.	X		X
57. Productus parvus?			R
58. Diaphragmus elegans	X		X
59. Echinoconchus genevievensis	X		
60. Camarotoechia aff. grosvenori		R	
61. Allorhynchus cf. macra		R	
62. Pugnoides ottumwa (3 varieties)			R
63. Pugnax wortheni?		R	
64. Camarophoria aff. explanata			R
65. Dielasma cf. formosum	X	O	O
66. Dielasma cf. illinoisense	X	O	O
67. Girtyella brevilobata	X	O	O
68. Girtyella indianensis	X	O	O
69. Girtyella cf. turgida	X	O	O
70. Spirifer pellaensis	X		R
71. Spirifer cf. bifurcata and breckinridgensis (Chester var.)	X		X
72. Spirifer cf. leidyi	X		X
73. Reticularia setigera	X		X
74. Spiriferina aff. spinosa	X		R
75. Spiriferina transversa var.	X		R
76. Spiriferina transversa var. or. n. sp.	X		
77. Spiriferina n. sp. 1 (Like S. norwoodana but has large spines)			R

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Composite List of Fossils in the Fredonia Oolite—Continued.

	Ohara relatives	Meramec relatives	Gasper relatives
78. Spiriferina n. sp. 2 (Like S. spinosa but has groove in fold)			R
79. Eumetria verneuliana	X	X	X
80. Cliothyridina cf. hirsuta and sublamellosa	X	O	O
81. Composita trinuclea	X	X	X
82. Pinna sp. (? new)			
83. Pteronites cf. spergensis	X	X	X
84. Pteronites? (n. gen.?) with rib in sinus			X
85. Aviculopecten cf. monroensis			X
86. Aviculopecten cf. talboti			
87. Aviculopecten n. sp.			X
88. Aviculopecten n. sp.			X
89. Pseudomonotis? sp.			R
90. Myalina sp.? (not M. monroensis, cf. M. st. ludovici)		O	O
91. Modiola illinoisensis			R
*Modiola fountainensis			R
92. Dreissina? sp.			X
93. Nucula illinoisensis			X
94. Nucula? sp. (with coarse concentric ridges)			
95. Leda curta			X
96. Leda cf. nasuta		O	O
97. Cypricardinia? indianensis		X	
98. Parallelodon minima			R
99. Parallelodon aff. minima, but has coarser radii and is not so long			
100. Parallelodon illinoisensis			X
101. Parallelodon n. sp.			
102. Sphenotus monroensis			X
*Sphenotus? octocostatus			R
103-104. Sphenotus, 2 undet. sp.			
105. Cypricardella cf. ellipticus		O	O
106. Cypricardella aff. oblonga		O	O
107. Schizodus depressus			X
108. Schizodus, near depressus but has sharp umbonal ridge			X
*Schizodus circulus			X

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Composite List of Fossils in the Fredonia Oolite—Continued.

	Ohara relatives	Meramec relatives	Gasper relatives
109. Schizodus sp.?			X
110. Edmondia fountainensis			X
*Edmondia genevievensis			X
111. Conocardium mesiale	O	O	
112. Conocardium aff. meekanum	O	O	
113. Astartella? sp.			R
*Laevidentalium venustum		X	X
114. Bellerophon sublaevis		X	X
115. Bellerophon sp. (not B. monroensis)			
116. Bucanopsis aff. textilis (band triplicate instead of simple)		O	O
*Euphemus lentiformis			R
117. Porcellia n. sp.			X
118-120. Platyceras, 3 new species or varieties of P. acutirostris	X	R	X
121. Straparollus planorbiformis		X	X
122. Straparollus quadrivolvis		X	X
123. Straparollus aff. spergenensis			X
124. Straparollus cf. subumbilicatus			X
125. Euomphalus similis	X		X
126. Euomphalus similis var. planus	X		X
127. Murchisonia (? Solenospira) turritella (? var. pygmaea Weller)		X	X
128. Murchisonia (? Solenospira) attenuata		X	X
129. Murchisonia (? Solenospira) vermicula		X	X
130. Solenospira illinoisensis			R
131. Pleurotomaria cf. trilineata		?	X
132. Pleurotomaria aff. subglobosa			X
133. Pleurotomaria sp. cf. (Cyclonema angulatum Hall)		R	
134-135. Pleurotomaria, 2 undet. species			
136. Ptychomphalus (?) sinuata			X
137. Ptychomphalus (?) wortheni			
*Ptychomphalus (?) depressus			X
138. Naticopsis cf. carleyana		?	X
139. Naticopsis wortheni			X
140. Naticopsis waterlooensis?			R
141. Loxonema wortheni?			

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Composite List of Fossils in the Fredonia Oolite—Continued.

	Ohara relatives	Meramec relatives	Gasper relatives
142. Loxonema n. sp. (Large, surface broadly waved)			X
143. Loxonema n. sp. (Short, obscurely waved)			
144. Holopea? aff. proutana (Spire too low and volutions more ventricose)			R
145. Meekospira minuta			X
146. Bulimorpha whitfieldi			X
147. Bulimorpha cf. canaliculata		O	O
*Bulimorpha pygmaea			R
148. Soleniscus sp.			R
149. Leperditia carbonaria		X	X
150. ? Cytherellina glandella		X	X
151. Phillipsia sp.	X		
	X-R-O	X-R-O	X-R-O
	54– 4– 2	16–12–21	56–36–19

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FOSSILS OF THE OHARA MEMBER OF THE STE. GENEVIEVE LIMESTONE.—Most of the fossils listed below were collected and separately listed in 1889 according to two zones. The lower of these zones comprised the beds in the Cedar Hill section, near Princeton, between 28 and 53 feet above the Rosiclare sandstone. Practically all of the positively located material from this zone was collected on Cedar Hill. The higher zone is the shaly one 53 to 75 feet above the Rosiclare sandstone at Cedar Hill. As this bed is not so profusely fossiliferous here as in Crittenden County, the list of its fossils was compiled chiefly from collections made at localities to the west and north of Marion. The lower 25 feet of the Ohara, that is, the beds beneath the brecciated layer which locally marks the base of the "upper Ohara," contains very few good fossils. The top or fourth zone of the member, however, is fossiliferous, and a large percentage of its species is distinct from those found in the next underlying zone. As explained on preceding pages, the fauna of this upper zone was not collected as such until very recently, and the small collections made from it in 1902 and 1903 were erroneously believed to have come from a supposed limestone bed in the overlying Aux Vases sandstone.

In the following composite list the ranges of the fossils of the three zones (second, third, and fourth) are separately indicated by a cross in the columns to the right, each of the columns being designated by its proper caption, namely, zone 2, zone 3, or zone 4. Earlier or later occurrences of species are indicated in the fourth column by letters, M signifying that the species so marked is found also in either the Spergen or the St. Louis limestone of the Meramec series, F in the Fredonia, G in the Gasper, and D in the Glen Dean formation. Those species that are not so marked are for the present to be regarded as confined to and, therefore, as characteristic of the Ohara member.

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Fossils of the Ohara Member of the Ste. Genevieve Limestone in Caldwell and Crittenden Counties.

	Zone 2	Zone 3	Zone 4	Other occurrences
1. Zaphrentis pellaensis	X	X	X	F G
2. Zaphrentis spinulosa	X	X	X	F D
3. Amplexus geniculatus		X		
4. Platycrinus huntsvillae	X	X		F
5. Platycrinus sp.	X			? F
6. Zeacrinus? or Pachycrinus sp. (cf. Z. intermedius) (same as Huntsville)	X	X		? F
7. Eupachycrinus 14-brachiatus Lyon		X		
8. Talarocrinus trijugis	X	?	X	
9. Talarocrinus dewolfi Ulrich, n. sp.	X	X		
10. Talarocrinus buttsi Ulrich, n. sp.	X			
11. Batocrinus aff. euconus	X			F
12. Dizygocrinus superstes Ulrich, n. sp.	X			F
13. Dizygocrinus n. sp.		X		F
14. Dizygocrinus persculptus Ulrich, n. sp.	X			?
14a. Dizygocrinus unionensis Worthen		X		
15. Mesoblastus glaber		X		F G
16. Pentremites princetonensis Ulrich, n. sp.	X	X		F
17. Pentremites princetonensis var. 1	X	X		F
18. Pentremites pulchellus Ulrich, n. sp.	X	X		F
19. Pentremites pulchellus var.		X		F
20. Pentremites tuscumbiae Ulrich, n. sp.	X	X		F
21. Pentremites pinguis Ulrich, n. sp.		X		F
22. Pentremites downeyensis Ulrich, n. sp.		?	X	
23. Pentremites coronarius Ulrich, n. sp.	X	?	X	
24. Pentremites prematurus Ulrich, n. sp.		X	?	
25. Pentremites buttsi Ulrich, n. sp.		X	X	
26. Ortonia sp.		X		F
27. Fistulipora n. sp.	X	X	X	F G
28. Fistulipora, 3 species (Fredonia types)	X	X		F

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Fossils of the Ohara Member of the Ste. Genevieve Limestone in Caldwell and Crittenden Counties—Continued.

		Zone 2	Zone 3	Zone 4	Other occurrences
29.	Fistulipora, 3 species of later Chester types	X	X		G
30.	Stenopora tuberculata	X	X		M D
31.	Stenopora rudis		X		D
32.	Stenopora cf. ramosa	X			? D
33.	Anisotrypa fistulosa		X	X	F G
34.	Lioclema araneum		X		G D
35.	Streblotrypa cf. nicklesi		X		G D
36.	Rhombopora sp.		X		G
37.	Rhombopora cf. persimilis	?	X		F G
38.	Coeloconus rhombicus		X		
39.	Cystodictya n. sp. (aff. pustulosa)		X		F G
40.	Glyptopora punctipora		X	X	G
41.	Sphragiopora parasitica	X	X		G D
42.	Septopora cestriensis		X		F G
43.	Septopora aff. cestriensis	X			
44.	Septopora subquadrans?		X		G D
45.	Fenestella elevatipora		X		? F G D
46.	Fenestella flexuosa		X		G D
47.	Fenestella cestriensis	X	X	X	F G D
48.	Fenestella serratula	X	X	X	M D
49.	Fenestella tenax	X	X	X	M D
50.	Fenestella sp.		X		
51.	Polypora cf. cestriensis	X	X		G
52.	Polypora cf. corticosa		X	X	G D
53.	Archimedes cf. meekanus		X		F G ?D
54.	Lyropora aff. quincuncialis			X	?D
55.	Lyropora cf. subquadrans			X	?D
56.	Rhipidomella cf. dubia	X			?M F
57.	Orthothetes kaskaskiensis	X	X		F G D
58.	Streptorhynchus sp.	X			F
59.	Productus pileiformis	X	X	X	F ?D
60.	Productus inflatus			X	F G
61.	Diaphragmus elegans	X	X	X	F G ?D
62.	Echinoconchus genevievensis	X			F
63.	Dielasma cf. formosum	X	X		F G
64.	Dielasma cf. illinoiensis	X	X		F ?G
65.	Dielasma sp.	X	X		?G
66.	Girtyella brevilobata	X			F G
67.	Girtyella indianensis	X		X	F M ?G

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Fossils of the Ohara Member of the Ste. Genevieve Limestone in Caldwell and Crittenden Counties—Continued.

	Zone 2	Zone 3	Zone 4	Other occurrences
68. Girtyella cf. turgida	X	X		F G
69. Spirifer aff. increbescens		X	X	G
70. Spirifer pellaensis	X			F
71. Spirifer cf. leidyi	X	X		F G
72. Spirifer cf. bifurcata	X	X	X	F G
73. Reticularia setigera	X	X	X	F G
74. Spiriferina cf. norwoodana	X	X		?M
75. Spiriferina spinosa var.	?	X		F ?G
76. Spiriferina transversa var.	X	X	X	F ?G
77. Spiriferina n. sp. (aff. transversa)	X	X	X	F
78. Eumetria verneuilana	X	X		M F G
79. Eumetria cf. vera	X	X		G
80. Cliothyridina hirsuta	X	X		F G
81. Cliothyridina sublamellosa	?	X	X	F G D
82. Composita trinuclea	X	X	X	M F G
83. Composita n. sp.	X		X	
84. Modiola illinoiensis	X			F ?G
85. Pteronites spergenensis	X	X		F G
86. Allerisma, 3 species	X			
87. Conocardium aff. meekanum	X			
88. Conocardium cf. mesiale	X			
89. Platyceras cf. acutirostris	X	X		F G
90. Euomphalus similis	X			F G
91. Euomphalus similis var. planus	X			F G
92. Naticopsis sp.	X			
93. Phillipsia sp.	X	X		

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FAUNAS OF THE GASPER OOLITE.

The fauna of the Gasper oolite in Kentucky is perhaps the largest to be found in any single formation of the Chester series. That of the preceding Ste. Genevieve limestone and that in the succeeding Glen Dean limestone come the nearest to it in number of species. The Ste. Genevieve and Gasper faunas are similar not only in the number of their species but also to a very considerable extent in character and relative smallness and inconspicuousness of most of the fossils. Both formations require much time and labor to gather anything like a full representation of the life of their respective ages.

The simulating components of the Gasper and Ste. Genevieve faunas consist mainly of the recurrent Spergen types that are found locally in great abundance and variety in certain oolitic layers. Indeed, sample slabs of such fossiliferous oolitic rock from the two formations are often so much alike in lithologic character and fossil contents that they might easily be confused. Commonly, however, the Gasper slabs contain specimens of certain well-marked species of Pentremites and other fossils that are never seen in the oolites of the Ste. Genevieve which, on the other hand, contain other conspicuous fossils that have not been observed in the Gasper. As a rule, therefore, these truly characteristic remains afford an unfailing means of distinguishing the otherwise closely simulating beds.

At many places in Kentucky a shaly bed, ranging in thickness from a few inches to perhaps 8 or 10 feet, separates the mass of the formation into an upper and a lower limestone member, the two being approximately equal in volume. This shale is always full of fossils, most of them being Bryozoa, the lacelike fronds of *Fenestella* and allied genera being particularly abundant. The screwlike axes of several species of *Archimedes*, more or less broken remains of small cylindrical and flattened branching species, and colonies of incrusting forms are other Bryozoa commonly found in

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this shale. The general aspect of its fauna is strikingly different from that found in the immediately underlying and overlying limestones. On the other hand it is very like the faunas found in the shaly beds of the Ste. Genevieve limestone. Similarly fossiliferous shaly beds are often present also in the upper 10 to 30 feet of the Gasper. Both of these Gasper Bryozoan zones have been observed also in Tennessee and as far south as Huntsville, Ala. The practical absence of Bryozoa, particularly *Archimedes,* in the lower limestone of the Gasper and their abundance in the middle and upper divisions are especially noteworthy, because a similar distribution of these same specifically identified organisms obtains also in the respectively correlated Renault, Yankeetown, and Paint Creek formations in Illinois.

The lower limestone member, although many of the ledges are largely composed of the separated plates of crinoids and blastoids and fewer shells of brachiopods, has not supplied a large fauna in Kentucky. Here it comprises 9 or 10 brachiopods and 1 or 2 corals, but the most striking of its fossils are *Pentremites* of species that range upward in the formation but not beneath its base. They are strictly Gasper fossils. Most of the specimens, especially those weathered out of the massive limestones and oolites, are silicified; and in western Kentucky the finer details of structure are commonly somewhat obscured in the process of silicification. Farther east, however, in the vicinity of Bowling Green, the *Pentremites* are both more abundant and much better preserved. The same favorable statement may be made also of the Gasper Pentremites in central and eastern Tennessee and in the vicinity of Huntsville, Ala.

Recent study of the genus *Pentremites* shows that the Gasper specimens are divisible into a large number of species; and most of them promise to become exceedingly useful guide fossils. The species are widely distributed and as a rule identifiable specimens are easily procured. Except that they are commonly more numerous in the higher members, the main difference between the specimens found in the lower and upper beds of the formation is one of size, the same species reaching larger dimensions in the upper Gasper. In determining

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the correlates of the Gasper in the rocks of Illinois the testimony of the *Pentremites* is particularly illuminating and satisfactory. Comparison of collections from the two states shows that all of the Renault species occur in the lower Gasper in Kentucky, and all of the Paint Creek species have been found also in the middle and upper beds of the Gasper.

Good crinoids are rare in the lower member of the Gasper in Kentucky. Exceptions to this rule occur commonly only among the species of *Talarocrinus*, a genus in which the plates of the calyx are more firmly joined than in most other crinoids. More favorable conditions for preservation obtained in the Mississippi Valley north of Chester, Ill. Here, therefore, the efforts of the collector of crinoids have been rewarded with gratifying success. Among many excellent crinoid localities those in the Renault formation in Illinois are important in this connection. Good specimens of about 15 species, among them a number of highly characteristic forms, have been procured from these localities.

Because of its bearing on correlation problems it is important to note that about half of these same Renault crinoids has been found in the middle part of the Monte Sana limestone near Huntsville, Ala., which contains also the lowest appearance of the Gasper *Pentremites*. All of this evidence will be presented in detail in the next chapter which is devoted to the discussion of the age relations of the Chester faunas.

East of Princeton, Ky., the upper limestone of the Gasper seems to be more variable in its thickness as a whole and in the composition and areal distribution of its beds than the lower member. The variation in thickness seems to be by reduction through loss of both lower and upper layers northwestward from the area of the Cumberland Plateau. The greatest thickness observed is in Franklin County, Tenn. Here the Gasper part of the Monte Sana is about 175 feet thick, of which something like 105 feet belongs to the upper member. In the vicinity of Bowling Green, Ky., the Gasper as a whole is approximately 100 feet thick, with not over 60 feet belonging to the upper member. Nearly the same proportions are maintained across the area between Bowling

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Green and the southeastern edge of Caldwell County. Westward beyond this county boundary the lower member apparently pinches out completely before reaching Crittenden County, whereas the upper member becomes shaly and finally passes into the Ridenhower shale of southern Illinois. A sketch illustrating these changes in the Gasper between Bowling Green and southern Illinois, and also the stratigraphic relations of the Gasper to underlying and overlying formations may be found in Part II which deals with the stratigraphy of the Chester series.

Viewed as a whole, the fauna of the limestones in the upper member differs decidedly from that found in the lower limestone and in the intervening shale. This fact, as well as the general nature of the difference, has been already mentioned. The specific details are more clearly brought out in comparing the occurrences of the fossils as indicated in the columns on the right of the following list of Gasper oolite fossils.

The fourth column, with letters instead of crosses, indicates that species so marked have been found in older or younger formations. M signifies that the species is known to occur in some Meramec formation, F in the Fredonia, O in the Ohara, D in the Glen Dean, R in the Renault, and RP when in both or either the Renault or the Paint Creek formations in Illinois, and P when observed only in Paint Creek collections. MB, or FB, or OB means that the species ranges from the Spergen, or the Fredonia, or the Ohara to some undetermined horizon in the Birdsville. Those without any of these letters in the last column are provisionally regarded as characteristic of the formation. Doubtless when the Birdsville faunas are thoroughly studied other Gasper species will be found to range into the formations of the higher group. On the contrary, too, some of those now regarded as ranging into the Birdsville will be distinguished.

It should be borne in mind that this list comprises only those species which had been collected by me in 1888-90 at three places between Princeton and Hopkinsville. Including the other species which have been found in the Gasper zone to the east and south, the total known

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fauna of the formation is increased by at least 35 species. Many of these additional species, in part mentioned in following discussions, are known also in the Renault and Paint Creek formations in Illinois.

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Fossils of the Gasper Oolite in Caldwell and Christian Counties.

	Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
1. Zaphrentis spinulosa	X	X		RP FB
2. Zaphrentis pellaensis			X	F O
3. Zaphrentis sp.			X	
4. Lonsdaleia? sp.			X	P
5. Cf. Ceratopora agglomerata			X	
6. Syringopora sp.			X	F
7. Pentremites godoni	X	X	X	P
8. Pentremites planus n. sp. (2 var.)	X	?	X	R P
9. Pentremites planus var. transitus n. var.	?		X	R P
10. Pentremites biconvexus n. sp.			X	P
11. Pentremites arctibrachiatus n. sp. (2 var.)	?		X	R
11a. Pentremites arctibrachiatus var. huntsvillensis n. var.	X		?	
12. Pentremites springeri n. sp.	X		X	P
13. Pentremites n. sp. aff. springeri and planus			X	
14. Pentremites aff. brevis n. sp.		X	X	
15. Pentremites pyriformis Say	X		X	R P
16. Pentremites pyriformis var. 1	?		X	
17. Pentremites pyriformis var. constrictus n. var.	X		X	
18. Pentremites pyriformis var. 3			X	P
19. Pentremites pyriformis var. 4	X		X	
20. Pentremites welleri n. sp.	X		X	R P
21. Pentremites welleri var.			X	P
22. Pentremites gemmiformis	X	?X	X	P
23. Pentremites canalis praeciptus n. var.		X		
24. Pentremites girtyi n. sp.	X		X	P
25. Pentremites patei n. sp.	?	X	X	P
26. Pentremites decipiens n. sp.	X		?	P
27. Pentremites abruptus n. sp.	X		X	R
28. Pentremites abruptus ? var.		X		R P
29. Mesoblastus glaber (spheroidalis M. and G.)			X	P
30. Archaeocidaris sp.			X	
31. Talarocrinus ovatus	X			R

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Fossils of the Gasper Oolite in Caldwell and Christian Counties—Con.

	Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
32. Talarocrinus symmetricus	X	?X		R
33. Talarocrinus similis n. sp.	X		?	
34. Talarocrinus depressus n. sp.			X	
35. Pterotocrinus sp., wings small, narrow, thin, outer extremity toothed		X		P
36. Pterotocrinus cf. depressus		X		?D
37. Pachylocrinus sp.		X		?R
38. Eupachycrinus sp.	X			?R
39. Agassizocrinus ovalis?			X	P
40. Cystodictya n. sp.		X		
41. Cystodictya aff. pustulosa*		X	X	F O P
42. Dichotrypa sp.			X	
43. Prismopora serrulata		X		D
44. Glyptopora punctipora			X	O P
45. Glyptopora n. sp.			X	P
46. Fenestella tenax		X	X	RP MB
47. Fenestella serratula		X	X	RP MB
48. Fenestella cestriensis		X		R O B
49. Polypora cf. corticosa		X		O B
50. Polypora approximata		X		P
51. Polypora cestriensis		X	X	P F B
52. Archimedes intermedia		X	X	D
53. Archimedes compactus?		X		?D
54. Archimedes meekanus		X	X	F B P
55. Archimedes invaginatus		X	X	D
56. Archimedes terebriformis			X	D P
57. Archimedes distans		X	X	D P
58. Archimedes sublaxus		X	X	D P
59. Archimedes laxus		?	X	D
60. Archimedes cf. lativolvis		X		G

*At least 20 of the species of Bryozoa here listed, including particularly Archimedes and other Fenestellidae, also Septopora, Rhombopora, Cystodictya, Stenopora, and Fistulipora, occur in the Paint Creek formation in Monroe and adjoining counties in Illinois. The notes on these Illinois specimens having been mislaid, I have identified again only those attached to slabs with Pentremites. These are noted in the fourth column. To prevent further misapprehension I shall add that the collections of Renault and Paint Creek fossils available to me are reasonably complete only so far as the blastoids, crinoids, and bryozoans are concerned, most of the brachiopods and other fossils collected at the same time having gone elsewhere.

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Fossils of the Gasper Oolite in Caldwell and Christian Counties—Con.

	Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
61. Thamniscus furcillatus		X		F D
62. Septopora cestriensis		X		F D
63. Septopora decipiens		X		D
64. Streblotrypa nicklesi		X		P O B
65. Coeloconus granosus		X		P
66. Rhombopora persimilis		X	X	P F B
67. Rhombopora tenuirama		X		D
68. Rhombopora tabulata		X		P D
69. Anisotrypa symmetrica?		X		? D
70. Anisotrypa fistulosa?		X		F O
71. Anisotrypa solida		X		D
72. Stenopora tuberculata		X	X	M B P
73. Stenopora cestriensis		X		F B P
74. Leioclema araneum		X		O B
75. Fistulipora cf. spergenensis			X	?M O
76. Fistulipora, 4 undet. species		X		F D
77. Spirorbis cf. nodulosus			X	M D
78. Plumulites sp.		X		
79. Crania sp.			X	
80. Streptorhynchus ulrichi			X	
81. Streptorhynchus sp. 2		X		
82. Orthothetes kaskaskiensis		X		F B
83. Orthothetes sp. 2		X		
84. Productus pileiformis			X	F B
85. Productus inflatus	X		X	F B
86. Productus arkansanus			X	?D
87. Diaphragmus montesanae			X	F B
88. Chonetes chesterensis	X		X	P
89. Dielasma aff. formosum*	X	X	X	?F O
90. Dielasma sp. 2			X	?F O
91. Dielasma sp. 3			X	?F O
92. Girtyella aff. turgida form No. 1		X	X	?F O
93. Girtyella aff. turgida form No. 2			X	?F O
94. Girtyella aff. turgida form No. 3			X	?F O
95. Girtyella aff. turgida form No. 4			X	?F O
96. Cliothyridina cf. hirsuta		X	X	M O
97. Cliothyridina sublamellosa	X	X	X	O B P

*These species and varieties of Dielasma and Girtyella are very closely allied to those in the Fredonia and Ohara members of the Ste. Genevieve.

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Fossils of the Gasper Oolite in Caldwell and Christian Counties—Con.

		Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
98.	Cliothyridina n. sp.			X	
99.	Composita trinuclea and varieties	X	X	X	M O P
100.	Eumetria vera		X		O B
101.	Eumetria verneuiliana	X	X	X	M B P
102.	Spirifer aff. increbescens	X	X	X	O P
103.	Spirifer cf. bifurcata	X		X	F O R
104.	Spirifer cf. leidyi			X	F O P
105.	Reticularia setigera		X		F B
106.	Spiriferina spinosa	X	X	X	F B P
107.	Spiriferina transversa		X	X	F B
108.	Spiriferina transversa var.			X	
109.	Aviculopecten aff. monroensis (same in Fredonia oolite)			X	F
110.	Aviculopecten aff. monroensis No. 2 (same in Fredonia oolite)			X	F
111.	Aviculopecten n. sp. (same in Fredonia oolite)			X	F
112.	Aviculopecten n. sp. (close ally in Fredonia oolite)			X	?F
113.	Aviculopecten? sp.?			X	
114.	Cf. Pteronites spergenensis			X	F O
115.	Myalina aff. st. ludovici			X	?F
116.	Modiola cf. illinoiensis			X	?F O
117.	Dreissina? sp.			X	F
118.	Nucula illinoiensis			X	F
119.	Nucula sp. 2			X	?F
120.	Nucula sp. 3			X	
121.	Leda curta			X	F
122.	Leda n. sp.?			X	
123.	Yoldia sp.			X	
124.	Parallelodon illinoiensis			X	F
125.	Parallelodon minima var.			X	?F
126.	Parallelodon n. sp.			X	
127.	Pleurophorus aff. Sphenotus monroensis and P. tropidophorus			X	
128.	Sphenotus? (Pleurophorus?) monroensis			X	F
129.	Murchisonia (?Solenospira) attenuata			X	F

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Fossils of the Gasper Oolite in Caldwell and Christian Counties—Con.

	Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
130. Murchisonia turritella?			X	F
131. Solenospira cf. illinoiensis			X	?F
132. Sphenotus aff. octocostatus			X	?F
133. Sphenotus n. sp.			X	
134. Edmondia fountainensis			X	F
135. Edmondia genevievensis			X	F
136. Edmondia sp.			X	
137. Astartella sp.			X	?F
138. Cypricardella cf. subelliptica			X	
139. Cypricardella aff. oblonga			X	
140. Cypricardella aff. oblonga var			X	
141. Schizodus circulus			X	F
142. Schizodus depressus			X	F
143. Schizodus cf. depressus			X	F
144. Schizodus sp. undet.			X	F
145. Laevidentalium venustum			X	M F
146. Bellerophon sublaevis			X	M F
147. Bucanopsis textilis			X	M ?F
148. Euphemus sp.			X	?F O
149. Porcellia n. sp.			X	F
150. Platyceras acutirostris et var.		X	X	M B P
151. Straparollus planorbiformis?			X	M B
152. Straparollus quadrivolvis			X	M B
153. Straparollus spergenensis			X	M B
154. Straparollus subumbilicatus var.			X	F
155. Euomphalus similis			X	F B
156. Euomphalus similis var. planus			X	F B
157. Pleurotomaria aff. trilineata			X	F
158. Pleurotomaria aff. subglobosa sp. 1			X	F
159. Pleurotomaria aff. subglobosa sp. 2			X	
160. Pleurotomaria n. sp.			X	
161. Ptychomphalus? sinuatus			X	F
162. Ptychomphalus? depressus			X	F
163. Naticopsis wortheni			X	F
164. Naticopsis carleyana			X	M
165. Naticopsis cf. carleyana			X	F
166. Naticopsis n. sp.			X	?F O
167. Naticopsis n. sp.			X	
168. Eotrochus aff. concavus			X	

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Fossils of the Gasper Oolite in Caldwell and Christian Counties—Con.

	Lower Limestone	Middle Shale	Upper Limestone	Other Occurrences
169. Eotrochus n. sp.			X	?F
170. Holopea? aff. proutana			X	?F
171. Holopea? (Soleniscus?) sp. 1			X	
172. Holopea? (Soleniscus?) sp. 2			X	
173. Holopea? (Macrochilina?) sp.			X	
174. Meekospira minuta			X	F
175. Orthonema sp.			X	
176. Loxonema n. sp.			X	F
177. Bulimorpha whitfieldi			X	F
178. Bulimorpha n. sp. (aff. B. canicu-lata)			X	
179. Bulimorpha cf. elongata			X	?M
180. Bulimorpha cf. pygmaea			X	?F
181. Chiton sp.			X	
182. Leperditia carbonaria	X		X	M B
183. ? Cytherellina glandella	X		X	M B
184. Phillipsia sp.			X	F B

A SANDSTONE FAUNA LOCALLY OBSERVED AT THE TOP OF THE GASPER.—A fossiliferous zone mentioned in a former paper* as belonging in the basal part of "Birdsville Bed 1" (Cypress sandstone) has been observed at Scottsburg, Caldwell County, Ky., and at other places in that vicinity. The bed—originally a strongly calcareous but now more or less shaly fine-grained sandstone—lies at the bottom of (or just beneath) the Cypress sandstone and over a bluish shale. It is only a foot or so in thickness but is filled with fossils preserved mainly as excellent molds of the exterior and interior. Recent study of these fossils gave rise to doubt as to their supposed Birdsville age, their relations to Gasper faunas being at least equally strong. A lithologically similar bed containing also the same kinds of fossils—especially the characteristic *Archimedes confertus*—has been observed at the top of the Ridenhower shale in the bluff

*Ulrich, E. O. U. S. Geol. Survey Prof. Paper 36, pp. 61, 63, 1905.

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just below Golconda, Ill. Here, also, it lies just under or at the base of the Cypress sandstone.

A list of the species found in an exposure of this bed less than a quarter of a mile east of the station at Scottsburg comprises the following 20 species. The collection was made in 1889 and the material studied and listed the following winter.

List of Fossils Found in a Thin Bed of Calcareous Sandstone at the Top of the Gasper or the Base of the Cypress Sandstone at Scottsburg, Ky.

***Fistulipora aff. spergenensis.**
Fistulipora sp. 2.
Fenestella serratula.
Fenestella tenax.
***Archimedes confertus.**
Polypora cestriensis.
Septopora cestriensis.
Crania sp.
Orthothetes kaskaskiensis.
***Productus pileiformis.**
Diaphragmus elegans?
***Spirifer breckinridgensis?**
Reticularia setigera.
***Spiriferina spinosa.**
***Cliothyridina cf. hirsuta and sublamellosa.**
***Composita cf. trinuclea.**
***Eumetria verneuilana?**
Dielasma sp.
Myalina sp.
Aviculopecten sp. (with rather coarse rays).

Eight of the entries in this list are preceded by an asterisk. The species so marked are represented in this collection by specimens that agree very closely with others found in underlying typical Gasper. No especially diagnostic features were observed on the unmarked species. So far as known they are as much like Birdsville varieties as Monte Sana. But none of them would seem out of place in a true Gasper fauna. On the basis of predominance of affinities, therefore, the bed in question may be regarded, provisionally, as late Gasper in age rather than early Cypress.

The only really characteristic fossil is the *Archi-*

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medes. As said, this species was found in a corresponding position near Golconda, Ill. It occurs also in Randolph County, Ill., some excellent specimens—in fact the original types of the species—having been found by me at two places south of Prairie du Rocher, both occurrences being in shale near or just beneath the base of the Okaw limestone. Apparently this well-marked species is an uncommonly accurate guide to some possibly transitional zone between the Monte Sana and Birdsville groups.

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AGE RELATIONS OF THE LOWER CHESTER OR MONTE SANA FAUNAL ZONES.

COMPARISON OF THE FREDONIA AND OHARA FAUNAS OF THE STE. GENEVIEVE LIMESTONE.—Referring to the preceding lists of fossils, that of the Fredonia is found to have a total of 156 entries. All but 7 of these were found in rocks of this age in Caldwell and Crittenden counties. The exceptions are species so far known only in the typical outcrops of the Ste. Genevieve limestone in the Mississippi Valley. These were added to the Kentucky list because the presence of the same forms, or their closest allies, in the upper member of the Gasper oolite in Kentucky gives them a definite bearing on the questioned Chester age of the Fredonia member.

Analysis of the Fredonia list and of the column showing the relations of this fauna to that found in the middle and upper beds of the Ohara member shows that of the 148 species from the Fredonia member of the Ste. Genevieve limestone in western Kentucky, 54 in unappreciably modified forms are found in the same region in the Ohara member *above* the conglomerate bed in the Ohara near Princeton. In other words, 54 species or 36 per cent. of the Fredonia fauna of western Kentucky ranges upward without recognizable modification into the middle or upper beds of the Ohara member. The actual strength of the relationship of these two faunas is greatly obscured by the relatively small representation of the Spergen fauna in the Ohara. If these persistent types were eliminated from the two lists, the proportion of species common to the Fredonia and Ohara faunas would be greatly increased.

Evidently invasions of western Kentucky by descendants of the Spergen fauna were temporarily suspended during Ohara time. As is well known, this association of minute organisms always avoided areas in which shaly deposits were being formed. However, though absent in western Kentucky, it seems not improbable that more favorable conditions obtained locally in the Mississippi Valley and that the prolific Ste. Genevieve fauna recently described by Weller* is in fact the

*Weller, Stuart. Description of a Ste. Genevieve limestone fauna from Monroe County, Illinois. Contr. Walker Mus., Vol. 1, No. 10, 1916.

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Ohara facies and not the Fredonia. This possibility is discussed on a following page.

Of the 54 species that are common to the Fredonia and the upper Ohara the majority are not sufficiently complex in structure to make them of the highest value in determining geological ages. This is evident from the range of the corals, Bryozoa, and Brachiopoda, most of which persist with practically unappreciable modification from the Fredonia, and in some instances from the Spergen, to and above the top of the Gasper. Much better indicators of the passage of time are the crinoids and blastoids. Still, the usefulness of the crinoids is somewhat limited by the difficulty of procuring specimens good enough for accurate specific identification. The blastoids, however, especially of the genus *Pentremites*, are more generally found and most of the specimens are accurately determinable.

The *Pentremites* of the Spergen and St. Louis are clearly and readily distinguishable from those of the Ste. Genevieve limestone. Similarly the *Pentremites* found in the Ohara are different from these in the Gasper oolite. But when we compare the *Pentremites* of the Fredonia with those in the middle part of the upper Ohara they are found to be surprisingly alike. Thus of eight species and varieties or mutations distinguished in studying the *Pentremites* of the Fredonia, six were found to occur also in the upper Ohara. This fact, in harmony with all the other data bearing on the question, argues strongly for the essential unity of the Ohara and Fredonia faunas and consequently against the idea of any considerable stratigraphic break between them. But we have not yet exhausted the evidence that tends to confirm my belief in the essential unity of the fauna of the Ste. Genevieve, including all of the Ohara.

When the report on western Kentucky was published in 1905, I was under the mistaken impression that *Platycrinus huntsvillae* is confined to the Fredonia member of the Ste. Genevieve limestone. As previously explained, the notes and collections made in 1888 to 1890 were not available when this report was written. However, when the delayed study of the recovered original notes and collections showed conclusively that speci-

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mens of *Platycrinus huntsvillae* were found above the conglomeratic bed at Cedar Hill near Princeton and again at a locality a few miles southwest of Marion, in Crittenden County, the misapprehension regarding the stratigraphic range of this crinoid was corrected. At both places, too, the *Platycrinus* is associated with three of the Batocrinidae that are common to the middle part of the Ohara and the Fredonia. Finally, at the Crittenden County locality these crinoids were accompanied by several species, among them the coral *Amplexus geniculatus*, known to occur only in faunal zone 3 of the Ohara. Thus, on the basis of associated fossils and stratigraphic position it is proved that the hitherto supposedly characteristic Fredonia fossil, *Platycrinus huntsvillae*, is found occasionally at least in Kentucky in beds well up in the part of the Ohara that Weller has correlated with his Renault formation.

That *Platycrinus huntsvillae* happens to be a rare fossil in the upper Ohara in western Kentucky does not affect the true indexical value of the species in correlation; for, after all, the relative abundance of individuals of a species at different localities, or, indeed, its presence at all, is determined by local physical conditions that may either promote or prevent, as the case may be, its existence at any given locality. The discovery of a single specimen that matches in every particular other specimens from localities more favored by the species is as positively indicative of their contemporaneity as if the individuals were equally abundant at the two places. The probability that *Platycrinus huntsvillae* did thrive in northern Alabama during the time of the Ohara will be discussed in following paragraphs.

The status of even *Pugnax ottumwa* as a characteristic Fredonia fossil is not firmly fixed. I have, namely, a small slab containing several of the Chester Bryozoa commonly found in the upper Ohara, and embedded with these is a specimen of *Pugnax ottumwa*. This slab forms part of a small collection taken from a shaly limestone many years ago along the Marion road near Bethel school, whether from an upper Ohara bed or a lower position is at present uncertain. In either case

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one or more fossils must go out of the range previously assigned to them.

Again, as regards the range and exact age of the several occurrences of *Meekopora eximia* Ulrich: The types of this species came from beds supposed to belong in the Ste. Genevieve limestone in Monroe County, Ill. The same species occurs at Pella, Iowa. In western Kentucky it is unknown in the Fredonia but specimens that I have not succeeded in distinguishing occur rarely in the upper Ohara, more commonly in the upper Gasper near Huntsville, Ala., and at Newtonville, Ohio, in the Maxville limestone which contains Gasper *Pentremites* and other fossils and now seems to mean an extension of the Gasper rather than of the Ste. Genevieve as I believed formerly.

In view of these Gasper and Ohara occurrences of this beautiful bryozoan, are we sure that the beds in which it is found in Illinois and Iowa are of Fredonia age and not late Ohara?

Finally, does the Ste. Genevieve part of the Monte Sana limestone in the vicinity of Huntsville, Ala., consist of only the Fredonia member, or does it include beds at the top representing the upper Ohara of Kentucky? The lower half or two-thirds of the Ste. Genevieve in the Monte Sana section contains columnals and basal plates precisely like those in the Fredonia that are, perhaps properly, referred to *Platycrinus huntsvillae*. But there is some ground for the suspicion that the top beds of the Ste. Genevieve limestone near Huntsville may really be of Ohara age. These questioned upper beds locally contain somewhat shaly bands out of which came the original types of *Platycrinus huntsvillae* and subsequently the thousands of complete specimens on which our knowledge of the species is mainly based. It is certainly a fact that the columnals of the *Platycrinus* in these higher beds commonly have stronger spines on the periphery than do the Fredonia specimens, agreeing in this respect with the upper Ohara specimens from western Kentucky. This suggestion seems to be corroborated by the testimony of the associated *Pentremites* which agree on the whole rather better with the combination of varieties and mutations that is found in the

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upper Ohara in Kentucky than with the forms that occur in the Fredonia member. The evidence of six other crinoids which occur in this upper zone near Huntsville, Ala., on the same slabs with *Platycrinus huntsvillae* likewise tends to give this zone a younger aspect than Fredonia. In fact one of these crinoids has been identified by Wachsmuth and Springer, and now again by the latter, with *Camptocrinus cirrifer*, the types of which came from either the Gasper or the Glen Dean formation at Sloans Valley, Ky. Two others—*Decadocrinus fountainensis* and *Scytalocrinus decabrachiatus*—are very similar to and according to Mr. Springer indistinguishable from species found in the Renault of Illinois and in the Gasper near Huntsville, Ala. This significant association of crinoids and its bearing on the relations of the Ohara to the Renault is discussed in a following section.

These reasons strongly incline me to the belief that in Alabama, as in Kentucky, *Platycrinus huntsvillae* existed during and perhaps to the close of Ohara time.

If the foregoing considerations do not suffice there is yet another way through which we may arrive at a fair estimate of the actual closeness of the affiliations of these two—lower and upper—Ste. Genevieve faunas. This is accomplished by calculating the percentages in terms of the Ohara faunal list instead of the Fredonia list. Thus, of the total of 93 species listed from the upper Ohara, 54 appear also in the Fredonia list. In other words, about 58 per cent. of the upper Ohara fauna maintained its existence without appreciable modification from the time of the Fredonia to near the close of the Ohara. Moreover, 20 of the 54 continued practically unchanged into the Gasper, and 11 others—making a total of 65 out of 93—have their nearest allies in the same preceding and succeeding limestones.

Considering the critical nature of the faunal studies on which the lists are based, the fact that 58 per cent. of the Ohara fauna is common to the Fredonia member should perhaps be given greater weight than is accorded to the average run of faunal comparisons. We should remember also that much of the difference in their respective faunas is most probably due to differ-

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ences in prevailing bottom conditions which produced shaly deposits in the Ohara and massive oolitic ledges in the Fredonia. Even without such extra weight the faunal similarity between the Fredonia and the upper Ohara is surprisingly great. At any rate it is quite sufficient to effectually negative the claim made by Weller that an important stratigraphic and faunal break occurred between these two fossiliferous zones. Granting any break at all between them, it certainly had no greater effect on the composition and evolution of the Mississippian fauna in Kentucky than occurred in passing from the lower part of the Fredonia to its upper 60 feet. And compared with the much more thorough break between the St. Louis and the Fredonia, the assumed break within the Ohara seems almost negligible. In fact "breaks" or changes in the composition of marine faunas comparable to the latter are the rule in all formations that comprise two or more kinds of sedimentary deposits.

FAUNAL BREAK BETWEEN THE ST. LOUIS AND STE. GENEVIEVE LIMESTONES.—Because of their bearing on the natural position of the Meramec-Chester boundary, the most important facts concerning the Fredonia fauna remain to be mentioned. These are (1) that of the 155 species listed all but 16 appear here for the first time; and (2) that of the 16 species which are carried up unchanged from Meramec formations, 15 pass upward into the Gasper. Obviously, this is an extraordinary break in the life of the Mississippian seas. In thoroughness it exceeds by far the break that separates the upper Ohara from the Fredonia. It is much greater also than the break between the faunas of the Ohara and the succeeding Gasper oolite.

When these facts are considered in connection with the very strong affiliation already shown to exist between the fossil life of the Fredonia and that of the middle and upper Ohara beds, it seems clear that not only the lower third of the Ohara but its middle and upper parts as well should be referred to the same stratigraphic group or series that contains the Fredonia. In fact the systematic relations of the Fredonia and Ohara mem-

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bers of the Ste. Genevieve limestone are essentially the same as those which unite the upper and lower members of the Gasper oolite in one formation. Even if these relations between the Fredonia and the upper Ohara are not so intimate as I believe them to be, they are yet far too close to give anything like adequate support to the view that so important a boundary as that of the base of the Chester group is to be drawn between them.

This recently advocated view is further discredited by the close faunal affiliation that will be shown to exist between the Fredonia on the one hand and the Gasper oolite on the other. Considering all of this fossil testimony together, and supplementing it still further with the fact that the Chester age of the upper Ohara is generally conceded and that the Gasper lies so high in the Chester that its age has never been questioned, the fossil evidence seems so uniform in trend and so incontestible in character that only one conclusion seems possible. This conclusion is that Hall (1858), Worthen (1858 and 1869), and Safford (1869), in Alabama and Tennessee, and the writer more recently, in western Kentucky, Alabama, and Tennessee, were fully justified in drawing the base of the Chester between the top of the St. Louis and the base of the Ste. Genevieve. In short, whether the upper Mississippian is finally divided into two or three series, the natural boundary between the Meramec and the succeeding division lies between the St. Louis and the Ste. Genevieve limestones.

RELATIONS OF THE FREDONIA AND GASPER FAUNAS.—In the third column to the right of the list of Fredonia fossils appropriate signs indicate the relations to the Gasper fauna. These show that of the 155 species and varieties, 56 species or 34+ per cent. of the total fauna are represented by indistinguishable forms in one or more of the three parts of the Gasper oolite. If we add to these 56 indistinguishable recurrences the 36 other species which have their nearest relatives in Gasper and younger beds, it gives a total of 92 Fredonia species, or nearly 60 per cent. of the total Fredonia fauna as listed, that exhibit more or less positive reations to the fauna of the Gasper. Finally, with the addition of 20

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or 21 species whose relations to older and younger faunas are indecisive, the total of the Gasper affinities gives an aggregate of 112 species, amounting to 73+ per cent. of the whole.

By the same methods the relations of Fredonia and Gasper faunas to Meramec faunas (Spergen and St. Louis) indicate that 16 species have continued without recognizable modification from these earlier stages to the Fredonia, and a total of 28 or 29 Fredonia species show positive affinities to Meramec faunas. The addition of the 21 species whose relations to earlier and later fossils are not decisively favorable to either gives a total of 50 species that have as close or closer affiliations with Meramec faunas than with Gasper or later species.

Contrasting these totals of 56=34 per cent., 92=60 per cent., and 112=73 per cent., which represent the several grades of alliance of the Fredonia and Gasper faunas, with 16=10+ per cent., 28=18+ per cent., and 50=30+ per cent., representing respectively the same grades of alliance between the Fredonia and Meramec faunas, the great preponderance of the Chester alliance of the lower or Fredonia member of the Ste. Genevieve seems undeniably established.

GREATEST FAUNAL BREAK WITHIN THE CHESTER SERIES.—So far as the facts are shown by rather large collections available to me, the faunal alliance of the Fredonia and the Gasper, particularly the upper part of the latter, is closer than is that between the Gasper and any one of the succeeding formations of the Birdsville group. In fact the greatest break, both faunally and stratigraphically, within the Chester series in Kentucky seems to be the one between the top of the Gasper and the base of the next succeeding bed that contains a marine fauna. Commonly the interval between the two is marked by a widely distributed sandstone supposed to correspond to the typical Cypress sandstone in Illinois.

Locally in western Kentucky, as in the vicinity of Scottsburg, a few feet of thin-bedded sandstone, there lying at the base of or just beneath the Cypress sandstone, contains remains of a prolific marine fauna. As the faunule resembles the Gasper fauna as much or more

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than any of the succeeding Birdsville faunas, it seems probable that this bed was laid down during the retreat of the sea that closed the lower Chester and preceded the beginning of the Birdsville stage. This arenaceous closing facies probably corresponds to the so-called Ruma formation in Randolph County, Ill. The succeeding true Cypress sandstone, however, suggests deposition on a coastal plain or beach and perhaps outlying bars. At any rate no other organic remains than land plants have been found in it. These have been observed in the Cypress in many places from Pope County, Ill., southeastward to Huntsville, Ala.

On these and other grounds the Chester has recently been divided at this break into an underlying group or formation composed mainly of more or less oolitic limestone to which the term Monte Sana* has been applied, and an overlying group of alternating sandstone, shale, and limestone formations that corresponds to my Birdsville formation.†

THE STE. GENEVIEVE FAUNA IN THE MISSISSIPPI VALLEY.—Until very recently the fauna of the Ste. Genevieve limestone as developed in the Mississippi Valley at and to the north of Ste. Genevieve, Mo., had not been defined as such. Shumard,‡ who named the formation, spoke of its distinctive fauna and mentioned some but never described any of its species. Meek and Worthen** and subsequently Worthen himself,*** described a considerable number of Ste. Genevieve fossils from localities in Monroe County, Ill., but these were referred to the fauna of the St. Louis limestone. Considering that the Ste. Genevieve fauna as developed in the Mississippi Valley consists almost entirely of little-changed descendants of the recurrent Spergen fauna, I think it not strange that Worthen never appreciated the distinctness of the typical Ste. Genevieve limestone from the St. Louis limestone and never recognized the equivalence of the former to the lower part of the limestone

*Ulrich, E. O. Revision of the Paleozoic systems. Geol. Soc. America Bull., Vol. 22, 1911.
†Ulrich, E. O. U. S. Geol. Survey Prof. Paper 36, 1905.
‡Shumard, B. F. St. Louis Acad. Sci. Trans., Vol. 1, p. 406, 1857.
**Meek, F. B., and Worthen, A. H. Illinois Geol. Survey, Vol. 2, 1866.
***Worthen, A. H. Illinois State Geol. Survey, Vol. 8, 1890.

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in his Monte Sana section near Huntsville, Ala., which previously he had referred unreservedly to his Chester group. In Hardin County, Ill., however, where the upper part of the Ste. Genevieve displays the somewhat more shaly and upwardly more complete facies that obtains also on the south side of the Ohio in Crittenden and Caldwell counties, Worthen recognized the Chester affiliations of the beds beginning with the Rosiclare sandstone.

In the first year or two of my work in western Kentucky, that is, in 1888 and 1889, I also believed the Ste. Genevieve to be a part of the St. Louis. Later, however, it was distinguished, first as a supposedly new intermediate formation to which the name Princeton limestone was applied,* then, after being satisfied of its identity with the Ste. Genevieve limestone of Missouri, as the basal formation of the Chester group.† On the last occasion a fair but incomplete list of the Kentucky facies of its fauna was published. This was accompanied by illustrations of a few of the most characteristic species.

As stated by Weller‡, this Kentucky list "does not properly express the fauna as it is known at Ste. Genevieve, Mo., and in Monroe and Randolph counties, Ill.," but I can not concede that its failure to do so is, as supposed by Weller, because it includes many species "which should really be referred to the Renault formation." To me it seems a case of regional differences in contemporaneous faunas occasioned mainly by variation in bottom conditions.

In the paper cited, Weller describes and illustrates a fauna of 56 species, 26 of them as new, collected from a single 17-foot bed of "white, arenaceous oolitic limestone," which belongs near the top of the formation in a bluff on Mountain Creek, near Waterloo, Ill. The basal 10 feet of the section at this place is referred to the St. Louis limestone but on what grounds is not clear. Between the possible, or, as I think, doubtful St.

*Ulrich, E. O. Geology and mineral resources of Crittenden County, Kentucky. "Crittenden Press," Dec., 1890. U. S. Geol. Survey Bull. 213, p. 207. 1903.

†Ulrich, E. O. U. S. Geol. Survey Prof. Paper 36, 1905.

‡Weller, Stuart. Description of a Ste. Genevieve limestone fauna from Monroe County, Illinois. Contr. Walker Mus., Vol. 1, No. 10, p. 243, 1916.

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Louis and the bed in which the described fauna is found are 28 feet of inter-bedded granular dense-textured oolitic and semi-oolitic limestones, with two thin discontinuous beds of green and purple shale near the top. The upper of these shales is very fossiliferous and will be referred to again.

The fauna described by Weller is known to me in part by specimens collected on a hurried visit to the same exposure. The remainder has been carefully studied by means of the figures and descriptions given in Weller's paper. As thus conceived by me the fauna does not correspond exactly with any association of species so far observed in the Fredonia member of the formation in Kentucky. On the contrary, it contains at least six species of which indistinguishable or at least very closely allied forms have been found in Kentucky only in the upper member of the Gasper. (See preceding list of Fredonia fossils in which they are distinguished by a prefixed *). I might have added to these the unidentified species of *Eotrochus*, a form differing in precisely the same manner from the Spergen oolite species *Eotrochus concavus* having been found in the Gasper. Also Weller's *Bembexia waterlooensis*, *Yoldia laevistriata* Meek and Worthen, and the small *Streptorhynchus* doubtfully referred to *Streptorhynchus minutus*, all of which resemble Gasper species rather than Fredonia fossils. Of course I do not mean to suggest that the fossiliferous oolite on Fountain Creek is of Gasper age. What I do purpose is to further emphasize the Chesterian affiliation of the Ste. Genevieve fauna in its typical expression. At the same time I wish to imply the not remote probability that the bed from which Weller collected the fossils represents some part of the Ohara and not the Fredonia.

The latter suggestion receives some support from fossils found in the band of purple shale that underlies the fossiliferous oolite in the creek section near Waterloo. Among other fossils, most of which would not be out of place in either the Ohara or the Fredonia fauna, this shale contains *Coeloconus rhombicus* which in Kentucky has been found only in the upper Ohara. The same species, together with many other Bryozoa of

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kinds found commonly enough in the shaly beds of the Ohara in western Kentucky, was found also at Ste. Genevieve, Mo., in a layer of purple calcareous shale lying near the top of the Ste. Genevieve, hence well above the horizon of the Rosiclare sandstone which is characteristically developed in the same place. At the time of its discovery I correlated this shale with zone 3 of the Ohara section in Kentucky. At present, however, I am inclined to give it a lower position—probably in zone 2 or possibly even in 1—having reached the conclusion that zones 3 and 4 are generally wanting in the Mississippi Valley sections. If this belief is well founded, then the missing zones measure the early part of the small hiatus that I conceive as commonly dividing the Ste. Genevieve from the base of the overlying Aux Vases sandstone. In western Kentucky and in Hardin County, Ill., this hiatus would be of correspondingly smaller magnitude than at Ste. Genevieve, Mo., and of course much smaller than it is in parts of Randolph and Monroe counties, Ill., where the Aux Vases locally rests on the St. Louis.

These upper two or three zones of the Ohara as developed in western Kentucky and Hardin County, Ill., are the ones thought by Weller to correspond in age to his Renault formation. Although many species were found to be common to the Fredonia and the Ohara, none of the Ohara fossils chiefly relied on by Weller in correlating the upper Ohara with the Renault proved strictly identifiable with the Renault species to which he has referred them. On the contrary, practically all the complexly constructed Ohara and Renault types of which the minor details of structure could be compared proved to be distinguishable, whether as "species" or "varieties" is immaterial.

I have already presented considerable evidence tending to show that the Ohara is wholly beneath the horizon of the Renault; and in following sections there will appear enough of detailed faunal evidence to prove conclusively that in Kentucky the beds corresponding in age to the Renault are included in the Gasper oolite.

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COMPARISON OF THE OHARA AND GASPER FAUNAS.—Comparison of the respective lists of Ohara and Gasper faunas shows that a large proportion—in fact about one-half—of the species of the former is found also in the latter. The similarity in these two faunas is made up mainly of those kinds of organisms that preferred the slightly muddy waters which laid down material that subsequently hardened into calcareous shale and shaly limestone. Of the common species those of the class Bryozoa are particularly notable, with the Brachiopoda next in number of species and individuals. The Mollusca are few in the shaly beds of both formations; nor are they prominent even in the solid limestones of the Ohara or in the subcrystalline lower limestone of the Gasper, but in the upper limestone they are locally very abundant.

The Bryozoa offer at least one generic type—*Coeloconus*—under which species are distinguishable that differ in easily recognizable but biologically not very important peculiarities and which, therefore, may be accepted as guide fossils of exceptional accuracy. Thus, at least in Kentucky, the presence of *Coeloconus rhombicus* may for the present be regarded as indicating the upper Ohara.* *Coeloconus granosa*, on the other hand, has been observed only in the shaly beds of the Gasper.

The *Pentremites*, I am glad to say, offer abundant and, so far as known, never-failing means of distinguishing Ohara and Gasper beds. The Ohara of western Kentucky, as shown in the preceding list, contains at least 10 distinguishable species and varieties of *Pentremites*. Not one of these is exactly identifiable among the 25 Gasper species and varieties of the same genus that I have differentiated and recognized with very few exceptions at two or more localities in Kentucky, Tennessee, and Alabama. This unexpectedly thorough distinctness of the Ohara and Gasper *Pentremites* is in sharp contrast to the great degree of likeness that obtains between the *Pentremites* of the upper Ohara and

*It would occasion no surprise to me if this species were found also in shaly beds of the Fredonia member. In fact the original types of C. rhombicus were collected on Fountain Creek, near Waterloo, Ill., from a thin bed of purple shale that Weller places in the Ste. Genevieve in or beneath the horizon of the lower Ohara. Still, Weller may be wrong on this, and the bed may really be of upper Ohara age.

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the Fredonia. Evidently the most important of the breaks within the Monte Sana or Lower Chester group occurred after the close of Ohara deposition and not at the time locally indicated by an intraformational conglomerate that in such places separates the "lower" Ohara (faunal zone 1) from the "upper" Ohara (faunal zones 2-4.)

The evidence of the crinoids is perfectly in accord with that of the Pentremites. Thus, whereas *Platycrinus huntsvillae*, and four species of *Dizygocrinus* and *Batocrinus* are represented by specifically indistinguishable specimens in both the Fredonia and the upper Ohara, no species of even their genera is known anywhere in the rocks of the age of the Gasper.* And this is not because crinoids are either rare or wanting in the latter position, but because the many species that have been found in the Gasper equivalent of the Monte Sana limestone near Huntsville, Ala., and in corresponding beds in the Mississippi Valley are, with few exceptions, quite different from the Ste. Genevieve species.

Though the faunal evidence as a whole indicates clearly enough that the Ste. Genevieve and Gasper are properly associated in one and the same subdivision of the Chester series, the testimony of the more precisely age-indicating fossils is as uniformly and indisputably opposed to the separation of the upper part of the Ohara from the remaining lower parts of the Ste. Genevieve as it is in favor of dividing the Monte Sana division along the plane of the Aux Vases sandstone. That this conclusion gives no countenance to the supposition that the upper Ohara is represented in Monroe County, Ill., by the Renault formation, and consequently that the Aux Vases sandstone is wanting in Kentucky, will be shown presently.

*Meek and Worthen in 1873 (Ill. Geol. Sur., vol. 5, p. 555, pl. 20, fig. 7) described and illustrated a small crinoid from the "Chester division of the Lower carboniferous series" in Pope County, Illinois, under the name Platycrinus parvulus. This would seem to be an exception to the above statement, but study of the species shows that it is not a true Platycrinus though possibly an atavistic member of the same family. Besides, the fossil may have been found in Englemann's "Lower Chester" which in Pope County would mean the Ohara member of the Ste. Genevieve rather than some higher formation.

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RELATIONS OF THE OHARA AND THE RENAULT FAUNAS.—In the introduction to a paper describing "A Ste. Genevieve limestone fauna from Monroe County, Ill.," Professor Weller* states that "the Ste. Genevieve limestone in Kentucky, as interpreted by Ulrich, includes beds which should really be referred to the Renault formation of the Chester group." The beds in question are those from which were procured all the fossils listed herein from the Ohara faunal zones 2, 3, and 4 of this work. In order to distinguish them from the underlying relatively barren zone 1, they are commonly referred to collectively as the "upper Ohara."

Critical comparison with the typical Renault fauna as known to me (see a following section) shows that the upper Ohara of Kentucky contains really only a few species common to the Illinois formation. What there is of such species is practically confined to the classes Bryozoa and Brachiopoda, and at that chiefly to the latter. But these common fossils are not confined to either or to both of the concerned beds but range with little or no appreciable modification from the Fredonia member of the Ste. Genevieve to the top of the Gasper in Kentucky and the Paint Creek formation in Illinois. For the present, therefore, their significance, in so far as it bears on the age relations of the upper Ohara to the Renault and as it is expressible in specific terms, may be set down as negligible.

But the faunas of the two beds comprise many other species that are actually competent witnesses. These are included mainly in the *Pentremites*, a genus of blastoids having a strong representation in both, and the crinoidea of which many species are known in the Renault and fewer in the Ohara. When the species and varieties of these two types of fossils are compared, very important and in part notable differences between the respective faunas of the two formations are observed. In general terms these differences have already been alluded to in various parts of this paper.

The distinctness of the *Pentremites* has been only very imperfectly appreciated heretofore. I had myself wrongfully identified one of the *Pentremites* in the top-

*Contr. Walker Mus., Vol. 1, No. 10, p. 243, 1916.

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most bed of the Ohara (zone 4 of the list) as *Pentremites godoni*.* However, in the course of my recent study of the *Pentremites* of the Chester group it became thoroughly clear that *Pentremites godoni* does not occur beneath the Gasper. In fact, it was shown that none of the 10 species and varieties of the genus found in the upper Ohara had ever been described; and also that the range of every one of them is limited above by the base of the overlying (Aux Vases) sandstone which in turn is overlain by the Gasper oolite. Probable derivatives, it is true, are found in the even larger Pentremital fauna of the Gasper, but in every instance the younger form is distinguishable from its Ste. Genevieve ancestors. On the other hand, most of the Ohara varieties proved indistinguishable—even as inconstant varieties or mutations—from their progenitors in the Fredonia. The evidence of the *Pentremites* thus appears to agree perfectly with the general trend of the testimony of the other classes of fossils in proving the essential unity of the Ste. Genevieve faunas, even "as interpreted by Ulrich in 1905," on the one hand, and their distinctness from the faunas of the Gasper, on the other.

What I have said about distinctness of the Ohara *Pentremites* from those in the Gasper may be repeated with equal positiveness when the comparison is extended to the species of the same class in the Renault formation. So far as it goes the series of Pentremites from typical exposures of this formation in Illinois, housed at present in the National Museum, harmonizes so exactly with the series of forms found in the lower Gasper of Kentucky, Tennessee, and Alabama (see following section for details) that the contemporaneity of the two series seems incontestible. On the basis of the *Pentremites*, therefore, correlation of the upper Ohara with the Renault is simply inconceivable.

When it comes to the crinoids, the first point to be considered is that whereas something like 20 species of this class have been found in the typical Renault of Illinois, only about 10 or 11 species have been found in the upper Ohara in Kentucky. But the more matter of

*The species referred to is now given the new name Pentremites downeyensis. It has narrow and convex, instead of concave, ambulacral areas.

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numbers of species and individuals can not have an important bearing on this question. The really significant feature is that none or at least only one or two of the Ohara species is represented by indistinguishable forms in the larger list of Renault species; and the exceptions to the rule would be merely species that began their known stratigraphic range in the Ohara. Moreover, the Ohara list comprises five Batocrinidae, apparently the last of their family, none being known above the base of the Aux Vases sandstone. Two others are closely allied species of *Platycrinus*, specimens of both of which were referred by Wachsmuth and Springer to *Platycrinus huntsvillae*. This genus also is generally supposed to have become extinct at the close of the Ste. Genevieve. The seventh is identified with *Scytalocrinus decabrachiatus*, typically a Ste. Genevieve limestone species in Monroe County, Ill. The same form occurs also at Huntsville, Ala., in association with *Platycrinus huntsvillae*, and in but slightly modified form in the Gasper zone in the Huntsville section. The eighth is *Eupachycrinus* 14-*brachiatus* Lyon, a peculiar crinoid though evidently related to an Illinois species which was described by Worthen under the name *Eupachycrinus asperatus*. The latter is said to be from the Chester group in Monroe County, Ill., and probably from the Renault formation.

Finally, the Ohara has supplied three species of *Talarocrinus*. One of these is a new species (*Talarocrinus buttsi* Ulrich) with the basal extremity of the calyx somewhat conical in form. The second is identified with *Talarocrinus trijugis* Miller and Gurley. This is the species most commonly found in the exposures along the Ohio River, and probably is the form mainly referred to by collectors who have identified the Renault fossil *Talarocrinus ovatus* Worthen in the Ohara. The third species of the genus is not uncommon in western Kentucky. Some 20 or 30 specimens were found in 1916 in an hour's search near Cerulean Springs. Though considerably like the Renault and lower Gasper *Talarocrinus ovatus* it is most certainly not the same. As there is no other species with which it might be identi-

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fied, it is here described as new under the name *Talarocrinus dewolfi.*

Careful comparison of all the known species of *Talarocrinus*, including seven or eight hitherto unnamed forms, has shown that these Ohara species are not identifiable with any of the four species known to me from the typical Renault of Illinois and Missouri; neither can they be referred to any of the eight or nine additional species that have been found with three of the four Renault species in the Gasper in Kentucky. Accordingly, Weller's already weakened correlation of the upper Ohara and Renault formations is further invalidated by just so much as it depends on the erroneous identification of Renault species of *Talarocrinus* in the former.

In the next following section three species in the list of crinoids common to the Gasper oolite at Huntsville, Ala., and the Renault formation in Monroe County, Ill., are marked with an asterisk (*). These species are distinguished from the others because they were originally founded on specimens collected by Worthen from limestone then, presumably, classified by him as belonging to the Chester (Kaskaskia) group. At any rate four species from this bed that Worthen had sent to Hall for study were described by the latter as Chester fossils. Subsequently, however, Worthen seems to have changed his mind concerning the age of this limestone, other crinoids from the same bed having been described, first by Meek and Worthen and, after the death of Meek, by Worthen himself, as belonging to the St. Louis limestone. In 1882 Worthen published a note (Illinois State Mus. Nat. Hist. Bull. No. 1, bottom p. 17) in which he changes the stratigraphic assignment of the four species described by Hall from Chester to St. Louis limestone. The crinoidal bed alluded to is now known to belong to the Ste. Genevieve limestone.

The crinoids from this Ste. Genevieve limestone locality have an exceptional interest here because some of the species are represented by scarcely distinguishable allies in the overlying beds of the Renault formation. They are indeed so close that Mr. Springer has seen fit to use the same specific names for both occur-

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rences. Our interest in the matter is heightened when we learn, further, that some of these same species similarly transgress the boundary between the *Platycrinus huntsvillae* beds (Ste. Genevieve) and the overlying Gasper horizon in the vicinity of Huntsville, Ala. Three of these transgressing species are, as noted above, included in the list mentioned in the preceding paragraph.

Possibly this community of Ste. Genevieve and Renault crinoids may, at first sight, seem to lend color to Professor Weller's belief in the equivalence of the upper Ohara and the Renault. But does it? In my opinion its effect on Professor Weller's supposition is really the opposite of favorable—in fact nothing short of disastrous. Remember that these crinoids are found in typical Ste. Genevieve limestone in Illinois and that in Alabama their lower occurrence is in beds crowded with *Platycrinus huntsvillae*, admittedly one of the most characteristic and certainly one of the most useful of the guide fossils of the Ste. Genevieve limestone. Remember also that Professor Weller protests against the inclusion of the Ste. Genevieve in the Chester, the base of this group being drawn by him in western Kentucky at the base of the upper Ohara which he regards as corresponding to the Renault and beneath which he assumes an hiatus that in the Mississippi Valley is partly occupied by the Aux Vases sandstone.

The Ohara has been a part of the Chester group in Illinois for more than 50 years. Its fauna is too clearly like that of the Chester to permit doubt of the correctness of this classification. Doubt may have been justifiable only with respect to the Chester age of the lower or Fredonia member of the Ste. Genevieve, although the evidence favoring this view published by me in 1905 should really have been accepted as sufficient to prove it. However, as my conclusion has been questioned, I have on preceding pages of this paper repeated and supplemented the previous argument with an array of corroborating facts that leave no room for denial. But all had not yet been said, for now we see that the transgressing Ste. Genevieve-Renault and Ste. Genevieve-Gasper crinoids occur at Huntsville in association with the rich-

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est colonies of *Platycrinus huntsvillae* known. Though I lean strongly to the view that this *Platycrinus* bed is really of upper Ohara age, this fact does not assist Professor Weller out of the difficulty of explaining these and many other, to him, disconcerting fossil occurrences. Either he must concede that *Platycrinus huntsvillae* is not confined to pre-Chester beds and that fossil evidence, however closely it may be investigated, is indecisive and contemporaneously variable in expression—consequently of little value in refined stratigraphic correlation—or he must admit that the Fredonia is more closely allied to the Chester than he believes, and the Ohara entirely older than the Renault.

The presence of species of *Lyropora* in the topmost zone of the Ohara also has been cited in confirmation of Weller's view. On the face of it this unexpected occurrence in the Ohara does appear as an important piece of corroborative evidence. Critically investigated, however, it also fails to carry out its promise. The Ohara and the Renault species of *Lyropora*, so far as they are known to me, *are not conspecific*. Of the two species of this genus that were found in the upper Ohara at Cedar Hill, near Princeton, one is a progenitor of the Birdsville species *Lyropora subquadrans*, the other a close ally of *Lyropora quincuncialis*. The Renault species, judging from a specimen procured from St. Mary's, Mo., is an early variety of a very different species, namely, *Lyropora ranosculum*. The last species might easily be confused with *Lyropora quincuncialis* because the U-shaped, thickened zoarial border is exceedingly similar in the two species. However, the network that is spread between the two arms of the U-shaped support is widely different in the two species. So far as the evidence of this genus of Bryozoa is available to me, the trend of its testimony is decisively opposed rather than favorable to the correlation of the upper Ohara with the Renault.

The real significance of the presence of such species of *Lyropora* in the upper Ohara is that it strengthens the evidence on which this part of the Ste. Genevieve was originally referred to the Chester series; and this evidence is made yet stronger by the association with the Lyroporas at Cedar Hill of a *Polypora* like *P. cor-*

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ticosa that is elsewhere known only in Birdsville formations.

I shall close this section with brief rebutting comments on certain Chester brachiopods that must have influenced Professor Weller's judgment in forming the conclusion that the base of the Chester should be drawn within the Ohara member and not at the base of the Ste. Genevieve.

Thus, *Diaphragmus elegans*—including, as we always did heretofore, the early form here distinguished as *D. montesanae*—is regarded as one of the Chester guide fossils. And so it is, but the "species" does not begin in the upper Ohara but ranges well down into the Fredonia member of the Ste. Genevieve. The Fredonia and the Ohara shells of *Diaphragmus elegans* are practically indistinguishable; the Gasper mutation, however, commonly has coarser ribs. Specimens from the several mentioned formations are figured on plate 4.

Productus inflatus also is a good Chester fossil, but like the preceding it is found occasionally in the Fredonia. Comparison of specimens indicates that in relative size of ribbing and general aspect the Fredonia specimens agree as well or even better with those from the Gasper oolite in Kentucky and the Okaw limestone in Illinois than with the Ohara examples.

Productus arkansanus, an even better Chester guide fossil than *P. inflatus*, also is found in very typical expression in the Fredonia. Specimens of this species and also of *P. inflatus* that were found in the Fredonia member of the Ste. Genevieve limestone in Caldwell County are photographically illustrated on plate 3.

Spiriferina spinosa is represented in both the Ohara and the Fredonia by a rather small variety in which the pattern of shell punctuation is somewhat coarser than in the typical Glen Dean form of the species. The Gasper variety differs slightly from both whereas a fourth variety, found in the top zone of the Ohara, agrees very well with the Gasper form except that its hinge is relatively longer. Given well-preserved material, the discrimination and assignment of these

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four varieties to their respective stratigraphic positions seems entirely practicable.

Finally, *Spiriferina transversa*, which also I regard as an excellent Chester guide fossil, begins in the Fredonia with a mutation that I can not distinguish from the common upper Ohara variety of the species. This variety has but 7 or 8 plications on each side of the fold whereas in the more typical Birdsville mutations of the species the number varies from 9 to 15. The Gasper form agrees better with the Ste. Genevieve variety than with the Birdsville specimens.

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PALEONTOLOGICALLY DETERMINED CORRELATES OF THE GASPER OOLITE IN THE MISSISSIPPI VALLEY.

The composition of the fauna of the Gasper oolite in Caldwell and Christian counties in Kentucky is as fully and accurately set forth in the list on previous pages as the collections in hand permit. Other collections, especially of blastoids and crinoids, from localities in Todd, Meade, Breckinridge, and Warren counties in west central Kentucky, and others from places on the eastern and western edges of the Cumberland Plateau in Tennessee, and in the vicinity of Huntsville, Ala., add considerably to the list given for Caldwell and Christian counties. Many of these additions are of very high importance in the solution of the question immediately before us.

Particularly important among these unlisted species are the crinoids from localities in Alabama now in the Springer collection at the National Museum. Regarding these it is well to mention in advance that all of the Chester crinoids mentioned here and most of those cited elsewhere in this paper have been identified primarily or, when their determination originated with me, the identifications have been either corrected or verified by Mr. Frank Springer. No effort has been spared to make the conclusions reached in this paper as authoritative and final as the material data and the personal advantages available to me would permit.

In the section on Monte Sana and on other hills and mountains to the east and south of Huntsville, Ala., the Gasper oolite zone forms the upper part of the Monte Sana limestone. The lower part of the latter is made up of oolitic and other limestones which clearly represent the Ste. Genevieve. The Gasper part is recognized here as to the north in Tennessee and southern Kentucky by abundance of such characteristic *Pentremites* as *P. godoni, P. planus,* and several varieties of *P. pyriformis.* Critically determined, all of these as well as some 20 less prolific species and varieties of *Pentremites* are confined to the Gasper; and approximately half of the total number have been found only in the upper half of this limestone.

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At the top of the Gasper part of the Monte Sana limestone, in the section of Monte Sana itself, is a shaly bed out of which R. S. Bassler and the writer procured a large collection of Bryozoa and fewer specimens of such other classes of fossils as are commonly associated with the Bryozoa in the shaly beds of the Gasper. Among these other fossils are good shells of *Chonetes chesterensis*. This *Chonetes* appears at two horizons in the Gasper of Kentucky. The lower of these is a thin bed lying near the middle of the lower member of the Gasper in Christian County, Ky. In this it is commonly associated with *Productus inflatus*. The second appearance is near the top of the Gasper where again it seems to occur either within or a few feet beneath a bed holding *Productus inflatus*.

The Bryozoa of this shaly top bed of the Gasper at Monte Sana include many axes of at least six species of *Archimedes*, and of the smaller ramose types more than a dozen species of *Rhombopora*, *Streblotrypa*, *Anisotrypa*, and *Cystodictya*. Above this bed comes a sandstone, in fact the only sandstone in the Chester series in Monte Sana. Though not over 10 feet in thickness here, this sandstone is a very important lithologic datum plane—probably the most important within the Chester series. Apparently it extends without interruption through Tennessee and Kentucky to southern Illinois, its thickness increasing rather steadily in that direction to a maximum of perhaps more than 150 feet. It is the Cypress sandstone of Engelmann 1862, not Ulrich 1905) and Birdsville bed 1 of Ulrich.*

Though not fully established, it yet seems highly probable that the Bryozoan bed next beneath the Cypress sandstone in Monte Sana corresponds to the shaly and as a rule similarly fossiliferous bed that is often present in Kentucky sections at or but a few feet beneath the top of the Gasper limestone.

*It may help in explaining how a number of Gasper species of crinoids came to be described or listed by Lyon, Wachsmuth and Springer, and others as from the St. Louis limestone, to know that in those areas in southern Kentucky, Tennessee, and Alabama in which both the Aux Vases sandstone and the Sample sandstone are not developed, the base of the Chester series was drawn either at the base of this more persistent Cypress sandstone or at some indefinite plane beneath the top of the underlying limstone of the Monte Sana group. The confusion of the three mentioned sandstones is responsible also for many errors in the stratigraphic assignment of post-Gasper Chester species.

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EVIDENCE OF THE BRYOZOA.—Speaking of the Bryozoa, it is important to note that with rare exceptions the fossils in this class in the Gasper oolite in Kentucky and in that part of the Monte Sana limestone in Tennessee and Alabama which corresponds to the Gasper are practically confined to the middle and upper parts of the formation. Particularly notable is the contrast in the development of species of *Archimedes*, the remains of these being exceedingly rare in the lower Gasper whereas in the higher beds they are never rare and, on the contrary, often are very abundant. The stratigraphic importance of this fact is twofold: first, it helps in discriminating the lower beds of the Gasper from the upper; second, it assists in correlating the members of the Gasper with Chester formations in southwestern Illinois where a similar distribution of the same Bryozoa obtains in the Renault and the Paint Creek. *Archimedes* and other Bryozoa are rare in the former but very common in the latter.

RENAULT CRINOIDS IN THE GASPER.—Many species of crinoids have been found in the Renault formation in Monroe County, Ill. Their preservation is excellent and their specific determination, therefore, may be carried out with relative ease and uncommon accuracy. Only one other area in America has provided this crinoid fauna in anything like the same variety, abundance, and perfection of specimens. This is in the hills to the east and south of Huntsville, Ala. In these they have been found in the upper or Gasper part of the Monte Sana limestone.

The crinoidal limestones in the corresponding beds of the Gasper in Kentucky indicate a similarly profuse development of this class of organisms also, but here the conditions of preservation were much less favorable than at the mentioned localities in Illinois and Alabama. In Kentucky the calyces and arms of the crinoids were more or less completely dismembered, only those calyces being preserved intact in which the component plates are uncommonly thick and the calyx correspondingly resistant to wave action. The species of *Talarocrinus*, which genus includes all of the crinoids at

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all common in the Gasper oolite of Kentucky, are of this nature.

In the section of Monte Sana, at Huntsville, prepared by me in 1904, the thickness of the Monte Sana limestone is estimated at 200 to 225 feet. Worthen's earlier estimate made it 250 feet. This is divided about equally between the Ste. Genevieve and the Gasper, the 100 to 110 feet assigned to the latter being more definitely ascertained than was the thickness ascribed to the Ste. Genevieve. Though no sharp boundary between the two divisions was observed, the presence of both formations in the Monte Sana section was none the less positively recognized. The paleontological aspects of the Ste. Genevieve part have already been discussed.

The Gasper crinoids mainly concerned in this inquiry occur in the 45-foot bed (No. 2 of section) whose top lies about 60 or 65 feet beneath the Hartselle (Cypress) sandstone. Measuring upward, the Gasper crinoid zone lies between 40 and 60 feet above the highest and most prolific of the *Platycrinus huntsvillae* zones. The beds in question consist largely of grayish, locally somewhat shaly, crinoidal limestone with subordinate amounts of sparingly fossiliferous oolitic and subcrystalline limestones. So far as known, crinoids are rare in the overlying beds of the Gasper in this section but they contain Pentremites in great variety and abundance. A similar vertical distribution of these two types of Pelmatozoa obtains also in the Gasper in Tennessee and Kentucky.

That the Gasper actually passes laterally into the upper part of the Monte Sana limestone has been established by tracing the concerned beds southward from Kentucky to Alabama. And, further, that the upper half of the Monte Sana includes representatives of both the upper and the lower members of the Gasper is indicated not only by this evidence of physical continuity of beds but also by the general faunal comparisons, and more reliably by corresponding limitations in the vertical range of particular species in Alabama and Kentucky.

Excluding those of *Talarocrinus*, Mr. Frank Springer has kindly prepared the following list of species col-

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lected from the lower Gasper bed at Huntsville, Ala., many years ago by his former associate, Mr. Charles Wachsmuth:

Crinoids from the Gasper Oolite Near Huntsville, Ala.

Catillicrinus carpenteri (Wachsmuth and Springer).
Onychocrinus distensus Worthen.
Abrotocrinus sculptus (Worthen).
***Pachylocrinus scoparius (Hall).**
Pachylocrinus venustus (Worthen).
Pachylocrinus salteri (Worthen).
***Scytalocrinus decabrachiatus (Hall).**
***Decadocrinus fountainensis (Worthen).**
Decadocrinus albersi (Miller and Gurley).

Species marked with an asterisk (*) were, according to Worthen,* originally based on specimens found in the Ste. Genevieve (St. Louis of Worthen) limestone in Monroe County, Ill. Mr. Springer points out that several of these crinoids, especially the first and third, are "highly specialized forms and therefore uncommonly valuable for correlation purposes." Finally, he says: "I have specimens of all of these species also from the Renault formation in Monroe County, Ill."

RENAULT SPECIES OF TALAROCRINUS IN THE LOWER GASPER IN KENTUCKY.—The crinoids of the genus *Talarocrinus* doubtless constitute the most important part of the fossil evidence on which Professor Weller bases his correlation of the "Upper Ohara" with the Renault. Strangely enough my study of the species of the same genus had led to altogether different conclusions. Why?

In the first place Professor Weller's conception of *Talarocrinus* hardly extended beyond the generic characters. Then, having observed that in Illinois most of the species of the genus, particularly those in which relative prominence of the basal plates causes constriction of the pelvis above them, are confined to the Renault, he assumed without further investigation that this type of structure is everywhere characteristic of this age. Accordingly, when he found somewhat similar

*Worthen, A. H. Illinois State Mus. Nat. Hist. Bull. 1, footnote p. 17, 1882.

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species in the upper Ohara, the beds containing them simply had to be of Renault age.

On the other hand, my recent studies of these crinoids descended to the minutest of specific and varietal details, and included not only all the species previously named and described but also nine others that had not been recognized before. That the consequent precision in identification of the fossils must be of greater value and accuracy in correlation than are the more generalized means previously employed seems too obvious to require further demonstration. Those wishing to acquaint themselves with the structural details of the fossils may acquire reasonably complete information by comparison of accompanying photographic illustrations of the species chiefly concerned in these inquiries.

These illustrations include the three species found in the Ohara in Pope and Hardin counties, Ill., and in Livingston, Crittenden and Caldwell counties, Ky. None of these is exactly like any of either the Renault or the Gasper species. In fact they are distinctly different; and two of them at least (*T. buttsi* and *T. dewolfi*) are clearly intermediate in character and presumably time relations between the *T. simplex* and *T. constrictus* of the preceding Spergen oolite stage on the one hand and the *T. ovatus* of the succeeding Gasper stage on the other. But the result of our investigations is quite different when we compare the species found in the typical Renault exposures in Monroe and adjacent parts of Randolph and St. Clair counties, Ill., with those found in the lower member of the Gasper in Kentucky. Thus, of four species of *Talarocrinus* so far observed in the crinoid bed of the typical Renault—*T. ovatus*, *T. symmetricus*, *T. delicatus* (Springer MS.), and *T. inflatus*—all but the last, which is confined to the Illinois localities, are found also in the lower Gasper in Caldwell and Breckinridge counties, Ky.

The following table shows the geological position, and so far as it goes also the geographical range, of each of the species of *Talarocrinus*. None passed across a stratigraphic boundary that for either physical or faunistic reasons might be ranked as important. Besides, strictly identifiable remains of them are among

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the commonest of the fossils of their respective zones. Indeed, such specimens are seldom wanting when these zones are present and favorably displayed for collecting. Evidently, then, these crinoids are uncommonly valuable and reliable as guide fossils.

List and Geological Distribution of the Species of Talarocrinus.

	Spergen Oolite.	Ohara Mem. Ste. Gen.	Lower Gasper	Upper Gasper	Renault of Ill. and Mo.	Paint Cr. of Ill.
Talarocrinus simplex	X					
Talarocrinus constrictus	X					
Talarocrinus buttsi		X				
Talarocrinus dewolfi		X				
Talarocrinus trijugis		X				
Talarocrinus patei			X			
Talarocrinus ovatus			X		X	
Talarocrinus symmetricus			X		X	
Talarocrinus delicatus (Springer MS.)			X		X	
Talarocrinus inflatus					X	
Talarocrinus similis			X			
Talarocrinus cf. similis				X		
Talarocrinus elegans			X			
Talarocrinus elegans spinigerus			X			
Talarocrinus decornis			X			
Talarocrinus subglobosus			X			
Talarocrinus sexlobatus			?	?		
Talarocrinus cornigerus			?	?		
Talarocrinus depressus				X		
Talarocrinus n. sp.						X

After this exceedingly important testimony of the crinoids it seems almost unnecessary to inquire further regarding the relations of the Renault to the Gasper. Still, as the crinoids listed by Mr. Springer are from Alabama, and the Gasper is named from a Kentucky locality at which none of his species has been found in determinable condition, it might still be questioned that the formation has been accurately identified at Huntsville. I shall therefore add the evidence of the *Pentremites*. Some of these occur with the crinoids,

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but in the vicinity of Huntsville the most prolific zones are in the next overlying upper 50 feet of the Monte Sana limestone. In corresponding parts of the Gasper limestone in Kentucky and Tennessee the remains of *Pentremites* are locally as abundant as in the best of the Alabama localities. At least nine-tenths of the species are common to the three states.

GASPER PENTREMITES IN ILLINOIS.—I have already mentioned the three most widely distributed and commonest of the Gasper species of *Pentremites*. In my recent study of the Chester species of the genus it was found that the thousands of specimens from the Gasper zone in Kentucky, Tennessee, and Alabama in the National Museum are divisible into 25 or more species and generally distinguishable varieties. Each of these is represented in our collections by eight or more good specimens, the numbers examined of *P. pyriformis*, *P. planus*, and *P. godini* ranging in each case from 1,000 to approximately 4,000. In four or five others the total of identifiable examples runs into the hundreds. With only a few exceptions all of these Gasper forms have been found at two or more widely separated localities; and at every place the collections comprise individuals of 3 to 20 or more of the varieties. The practical value of these *Pentremites* in recognizing the presence of the Gasper horizon, therefore, seems exceptionally great.

Now, of the 25 Gasper forms no less than 19 are represented in the National Museum and Springer collections by specimens from stratigraphically determined outcrops in Monroe County and adjacent areas in St. Clair and Randolph counties, Ill. Of these 19 Illinois species and varieties 6 were taken from a single positively determined Renault outcrop, and 5 of these were found also in beds definitely assigned to the Paint Creek formation by Professor Weller. The remaining 13 of the 19, or a total of 18 species and varieties of *Pentremites*, came from beds of unquestioned Paint Creek age. Finally, it is to be noted that the total of 19 Gasper species of *Pentremites* identified in the Renault and Paint Creek formations comprises all of the species of the genus so far observed in these Illinois

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formations. The following list shows their stratigraphic positions in Illinois and elsewhere. It brings out also other data that help in fixing the age of the Renault. With one exception all of these species are illustrated on accompanying plates.

Pentremites Found in the Renault and Paint Creek Formations in the Vicinity of Floraville, Illinois.

	Renault	Paint Creek	Lower Gasper	Middle and Upper Gasper
Pentremites symmetricus—slender mutation	X	X	X	X
Pentremites symmetricus—obese mutation	X	X		X
Pentremites abruptus		X		X
Pentremites abruptus var.	X	X	X	X
Pentremites pyriformis (young or small var.)	X	X	X	X
Pentremites pyriformis var. with rather short pelvis		X		X
Pentremites welleri		X		X
Pentremites patei		X		X
Pentremites girtyi		X		X
Pentremites genmiformis		X	?X	X
Pentremites decipiens		X		X
Pentremites arctibrachiatus	X		X	X
Pentremites springeri		X		X
Pentremites transitus Ulrich MS., typical form: closely allied to P. princetonensis and P. tuscumbiae on the one side and to P. planus and its varieties on the other	X	X	?	X
Pentremites transitus, var. with flat base resembling P. pinguis		X		
Pentremites planus, typical form		X		X
Pentremites planus, tall mutation		X		X
Pentremites planus, depressed mutation		X		X
Pentremites planus, var. with biconvex ambulacra		X		X
Pentremites godoni		X	?	X
Pentremites biconvexus		X		X

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Analysis of this table brings out some important facts. In the first place it shows that all of the Renault forms, except *P. arctibrachiatus,* ranged upward into the Paint Creek zones without suffering appreciable modification. Similarly, in Kentucky, most of the same forms—here, however, including *P. arctibrachiatus* instead of the obese variety of *P. symmetricus* which is unknown there—are common to the lower and the upper divisions of the Gasper oolite. Evidently, then, the time value of the break between the Renault and the Paint Creek is no greater than that between the lower and the upper members of the Gasper.

The table shows, further, that most of the species that are confined to the Paint Creek formation in Illinois are similarly restricted to the middle and upper parts of the Gasper in Kentucky and elsewhere to the south of Ohio River. Moreover, all of the Paint Creek *Pentremites* are found also in the upper beds of the Gasper.

We conclude, therefore, that the evidence of the *Pentremites* is uncompromisingly in favor of correlating only the upper beds of the Gasper with the Paint Creek formation of Illinois.

OTHER PAINT CREEK FOSSILS IN THE UPPER GASPER.—Collateral evidence tending to support the same view is supplied by the ancylosed basals of a species of *Agassizocrinus*—possibly *A. ovalis* Miller and Gurley—that differ from the same part in the common post-Cypress *A. conicus* in their smaller size and hemispheric instead of obconical form. Whatever the name of the crinoid to which they belong, such basal pieces occur in the Paint Creek formation in Randolph County, Ill., and in the middle to upper part of the Gasper limestone in Caldwell, Christian, Breckinridge, and Warren counties, Ky., and near Huntsville, Ala. The same is true in all respects of a variety of *Mesoblastus glaber* that Miller and Gurley described under the name *Granatocrinus sphaeroidalis.* And of similar tenor is the evidence of the Bryozoa. As stated above, many of these are common to the shaly beds in the middle and upper parts of the Gasper in Kentucky, Tennessee, and Ala-

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bama, on the one hand, and the Paint Creek formation in Randolph, St. Clair, and Monroe counties in Illinois on the other. For correlation purposes an undescribed species of *Cystodictya* and *Coeloconus granosus* are perhaps the most reliable of these Bryozoa.

Following the conclusion that only the upper beds of the Gasper are of Paint Creek age, the lower member of the Gasper remains by elimination as one of the two possible correlates of the Renault formation, the other being the upper Ohara. The choice between these two should not be difficult. Properly weighed, not a single piece of either direct or logically inferred evidence remains favoring correlation of any part of the Ohara with the Renault. On the other hand every means of arriving at the truth points clearly and without qualification of any kind to the correlation here advocated, namely, that the Renault is represented to the south of the Ohio by the lower member of the Gasper oolite.

GENERALIZED FAUNAL COMPARISONS.—Only one other method of correlating stratigraphic horizons remains to be considered in this connection. This is by generalized comparisons of the concerned fossil faunas. This method leads to less definite results than are attained by matching special groups and particular species and mutations. However, for the sake of completeness these coarser criteria also should be applied to the problem.

Disregarding the crinoids, most of which are found only very locally even in the Mississippi Valley, the fossil fauna of the Renault is almost exactly paralleled by that of the lower Gasper in Kentucky. Including the crinoids the typical Renault fauna as known to me comprises a total of about 35 species. Of these 23 or more are found in the lower Gasper in Kentucky and Alabama, and 9—most of them crinoids—are confined to the Renault in Illinois. Further, at least 7 of the 9 are found to the south of the Ohio River only in beds referred to the lower Gasper. Expressed in percentages, more than 60 per cent. (60 to 80+) of the Renault fauna is held in common with the lower Gasper in Kentucky and Alabama, and more than 80 per cent. of the fauna of the latter is found also in the Renault.

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The other species in both faunas—that is, the 26 species of the Renault that are not confined to this formation in Illinois, and the 16 to 20 lower Gasper species that are not confined to this zone in Kentucky and Alabama—consist mainly of forms that range through these zones from lower formations into higher beds of the Chester. The exceptions, though characteristic Gasper species, are common to both the lower and the upper divisions of the formation.

In strong contrast with these statements is the fact that none of the Ohara species that are not found also in the overlying and entirely distinct Gasper oolite in Kentucky has been found in the typical Renault. Again, none of the species that in Illinois are confined to the Renault is known to occur in the Ohara in western Kentucky. In other words, the species that are really characteristic of either of these zones in their respective states are not found in the other.

Comparison of the upper fauna as developed in Caldwell and Christian counties, and as listed here with the fauna of the Paint Creek formation in Illinois shows apparently decided differences. However, when these differences are analyzed it will be observed that they are occasioned almost entirely by the absence—in the Illinois formation—of the recurrent derivatives of the Spergen and Ste. Genevieve faunas which are so strongly represented in the essentially contemporaneous deposits in western Kentucky. Doubtless local or regional variations in bottom conditions, depth of water, and other environmental influences are responsible for the presence of these Spergen reminders in one place and their contemporaneous absence in another. Indeed, they are not generally distributed even in western and southern Kentucky, and they have not been observed at all in corresponding deposits in Tennessee and Alabama. In the latter places, therefore, the upper Gasper fauna is practically the same as that of the Paint Creek beds.

Thus out of a total Paint Creek fauna of approximately 50 species, 42 are found also in the middle and upper divisions of the Gasper in Kentucky, Tennessee, and Alabama. More than half of the 42 do not occur

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in the Renault in Illinois nor in the lower Gasper south of the Ohio; and most of those that are common to the Renault and the Paint Creek in the one case, and to the lower and upper parts of the Gasper in the other, are not confined to these formations but either began earlier or lasted longer, or did both.

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CONCLUDING STATEMENT.

In the foregoing pages I have applied all verified means of correlating geological formations—correlation by stratigraphic position, by lithologic similarity, by sequence of like lithologic units, faunas, and geologic events, by paleogeographic probabilities, by evolutional stages of species and faunas, by comparison of generalized faunal aspects, and by the more direct and precise matching of faunas, species, and particularly of systematically subordinate mutations of complexly constructed organic remains. The result in each trial has been as definite as the particular means employed permitted, and in every instance the predominant trend of the evidince has been clearly and uniformly favorable to the views here advocated. Such continuous corroboration would be impossible if my conclusions were not firmly grounded on incontrovertible facts and, in essential respects, absolutely true.

Whereas the relatively generalized criteria chiefly relied on hitherto may have left some room for legitimate argument, the more definite and positive nature of most of the new data presented in this paper has destroyed all chance for logical and successful refutation. So far as it may be done with the material and methods available, the case is settled. It can be unsettled again only by discrediting paleontological evidence in correlation; but that would be nothing short of stratigraphical suicide, for after all it is on the fossils that we mainly rely in establishing the time relations of geological events. If paleontological correlations have sometimes proved erroneous or imperfect, the fault has not lain with the fossils but with the paleontologist who endeavored to interpret their testimony. Studied in minutest detail and determined and matched as critically as possible the fossils tell the story both truly and fully.

I have conscientiously endeavored to fulfil these requirements in the present case; and I claim, therefore, that in all essential respects the conclusions reached are in harmony with the facts:

(1) The upper Gasper corresponds to the Ridenhower shale, and both to the Paint Creek formation. (2) The lower Gasper represents the Renault forma-

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tion, and the sandstone directly beneath the Gasper is the correlative of the Aux Vases sandstone which underlies the Renault. (3) The top of the Ohara is older than the Aux Vases sandstone and consequently no part of it can be of the age of the Renault. (4) The lower and middle parts at least of the Ohara most probably are represented in the Ste. Genevieve limestone in the Mississippi Valley and also in the Ste. Genevieve part of the Monte Sana limestone in Alabama. (5) The faunas of the Ohara and Fredonia members of the Ste. Genevieve limestone are more closely related than had been supposed and the relationship is sufficiently binding to require their classification in the same group and series. (6) The number of fossils held in common by the Fredonia and the St. Louis limestone is relatively small. (7) The most effective and the most widely displayed of the physical breaks in the upper Mississippian rocks is the one at the top of the St. Louis limestone. (8) The boundary between the Meramec and the succeeding series is most naturally and most conveniently drawn at the probably everywhere unconformable contact between the St. Louis and the Ste. Genevieve limestones.

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SUMMARY OF MATTER PERTAINING TO THE CORRELATION OF LOWER CHESTER FORMATIONS AND THE BASAL BOUNDARY OF THE CHESTER.

HISTORICAL PART.

(1.) The term Chester group was introduced and sufficiently defined by Worthen in 1866. It was intended to supplant, or at least render useless, the rival term Kaskaskia previously proposed by Hall. The two terms are not exactly synonymous and Worthen's conception of the group gives it the more natural foundation that finally gained for it the favor of geologists generally.

As defined by Worthen in the introductory chapter of Illinois State Geological Survey, volume 1, 1866, the Chester in the Mississippi Valley begins with the sandstone now known under the name Aux Vases. But in the same volume he definitely accepts Engelmann's classification of the upper Mississippian rocks in Hardin County, Ill., and he describes the Chester as embracing older beds than the Aux Vases, namely, the whole of what is now known as the Ohara and Rosiclare members of the Ste. Genevieve limestone. The boundary between the St. Louis and the Chester is here drawn by him and Engelmann at the base of the Rosiclare sandstone.

A decade or more preceding the publication of the Illinois State report in 1866, Worthen had found some fossils—particularly crinoids—at a place near Waterloo, Ill., where the Aux Vases is not developed. Evidently he regarded the limestone containing these crinoids as of Chester age, because when they were described by Hall in 1858 the latter referred them to the "Kaskaskia limestone." At the same time Hall published Worthen's section of Monte Sana, near Huntsville, Ala., and in this section beds now known to correspond in age to those at Waterloo and in fact to the whole of the Ste. Genevieve were definitely referred to the "Kaskaskia group." Moreover, a siliceous bed beneath them was correlated with the Aux Vases sandstone. Up to at least 1869 Worthen continued to refer

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the beds above the "siliceous" bed, which is now known to consist of St. Louis cherts, to his Chester group. But he did change his opinion regarding the equivalent beds near Waterloo, these being later (1882 or earlier) referred by him to the St. Louis limestone.

Every instance of Worthen's practice that we now know to have been inconsistent with this apparently purposed policy of drawing the base of the Chester at the top of the St. Louis limestone is occasioned by his unappreciative attitude toward the Ste. Genevieve limestone. He would not admit that in making his section of the Mississippian rocks in the Mississippi Valley south of St. Louis he has overlooked an important formation, namely, the Ste. Genevieve limestone.

(2.) Safford, in Tennessee, consistently drew the most important boundary within the Mississippian rocks of his State at the top of the St. Louis limestone. Over this came the "Mountain limestone" which he recognized as corresponding to Worthen's Chester group.

(3.) It seems probable that Engelmann acquired his first idea of the "lower Chester," as he called it, from the exposure about Rosiclare, and consequently that the section in Downeys Bluff supplied the original data for the standard sequence of his Divisions 8, 9, and 10, and not those in Johnson County. In other words, he correlated the really younger lower Chester beds in Johnson County with those in Downeys Bluff. These correlations in effect dropped two divisions—a sandstone and a limestone—from the complete sequence of the Chester series. Instead of 10 alternating sandstone and limestone divisions there should have been at least 12, Engelmann's No. 10 in Johnson County being in fact the Aux Vases sandstone which lies at the base of the bluff just below Golconda and caps Downeys Bluff at Rosiclare, and not his No. 8, as Engelmann believed. The Ohara, then, should have been called Division 11, and the Rosiclare Division 12.

(4.) As stated, the relations of the Cypress and Aux Vases sandstones were confused in Illinois by Engelmann, both at times being designated No. 8, either singly or together as a unit. Ulrich, in 1905, accepted

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Engelmann and Worthen's determination of the beds in Downeys Bluff at Rosiclare, Ill., as correct, and from there proceeded to trace the supposed No. 8 sandstone through the Kentucky counties, Engelmann's name Cypress being revived for it, whereas Keyes's term Aux Vases sandstone was reduced to synonymy. This procedure would have been correct if the sandstone capping Downeys Bluff had really been the same bed as Engelmann's No. 8 in Johnson County which is the real type of his Cypress sandstone. In 1905 Ulrich referred also the Kentucky term Big Clifty sandstone to synonmy under Cypress, but a subsequent visit to the type locality of the Big Clifty showed that the sandstone at this place is not the same as the Cypress of Ulrich's work in 1905 but corresponds to his bed 1 of the Birdsville, which in turn is the true Cypress of Engelmann.

In Johnson County, Ill., Engelmann distinguished the typical Cypress (his Chester division No. 8) from the Aux Vases sandstone, which he designated as No. 10, and between which and No. 8 he recognized a calcareous shale formation (now Ridenhower shale) that he called No. 9. In the Ohio bluffs in Pope and Hardin counties, however, he failed to observe the intervening shale (No. 9) and included both the overlying and underlying sandstone in one division which he identified as No. 8. No. 9 of the Johnson County section then was erroneously recognized in the Ohara member of the Ste. Genevieve, and No. 10 in the Rosiclare member.

(5.) Except (a) the mistaken recognition of the term Cypress sandstone instead of Aux Vases sandstone; (b) the asserted identity of the Big Clifty, Aux Vases, and Cypress sandstones; (c) the erroneous belief that the "Cypress" (Aux Vases) sandstone is locally tripartite, with a thin limestone member below its middle; and, (d) the unfortunate choice of the name "Tribune" for a perfectly valid though misunderstood stratigraphic unit in Kentucky, the sequence of beds and their classification as given in Professional Paper 36 is essentially correct. All of the erroneous statements concerning the "Tribune" (now Gasper) limestone in that work arose from the mistaken identification of the "Tribune" facies of the Spergen fauna in

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an oolitic bed found near the top of the Okaw limestone at Chester, Ill., which circumstance then seemed to require the correlation of the Okaw with the "Tribune." In the past few years, however, it has been shown that the fossiliferous oolite in the Okaw is younger than the top of the Gasper and that the upper part of the Gasper limestone passes northwestwardly from Caldwell County, Ky., into the shale (Ridenhower) which in Crittenden County, Ky., and in Hardin and Pope counties, Ill., separates the Aux Vases sandstone from the overlying Cypress sandstone.

STRATIGRAPHIC PART.

(1.) Sections in Randolph County, Ill., show that sandstones apparently corresponding to the Hardinsburg and Tar Springs of Kentucky occur locally in the Okaw basin.

(2.) The main difference between the section in the Okaw basin and those in southern Illinois and western Kentucky is that the interval occupied by the typical Okaw limestone in the former is taken up in the latter by the Cypress sandstone and the Golconda formation. In both areas the named formations are succeeded by the Hardinsburg sandstone, and this by the Glen Dean limestone. Because the fauna of the Golconda is very different from that of the typical Okaw, which would be almost inexplicable if the two were contemporaneous, and as the evolutional stage of certain fossil "species" is nearer that attained by Glen Dean than Okaw fossils, it is inferred (a) that the Golconda is not represented in the Okaw basin, and (b) that if any of the Kentucky Chester formations corresponds to the Okaw limestone it is the Cypress sandstone.

(3.) Whereas the interval between the Aux Vases sandstone and the Okaw limestone in the Randolph County section has been divided into four "formations" —the Renault, the Yankeetown, the Paint Creek, and the Ruma—the corresponding interval in Caldwell and Christian counties, Ky.—the correlations being made on the basis of minutely determined faunal contents—is viewed as a single formation, namely, the Gasper limestone. However, with the exception of the Yankeetown

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chert, each of the mentioned Randolph County "formations" is represented locally in the Gasper in the mentioned Kentucky counties by its characteristic lithologic peculiarities. The Yankeetown is represented at some places in Kentucky by shale, at others by sandstone (the Sample). The Renault is represented in Kentucky only by its off-shore limestone facies, there being no sandstone of this age south and southeast of Randolph County, Ill.

(4.) The Gasper limestone thins westwardly from Caldwell County by overlap and consequent loss of beds from below. The westernmost sections in the southeastern part of Crittenden County show, further, that the remaining upper Gasper contains proportionately more shale than does the corresponding part of the Gasper in eastern Caldwell and Christian counties. The shaly component continues to increase northwestward until the formation passes laterally into the Ridenhower shale, the transition being completed about on the line of the Marion fault. Accordingly, the Ridenhower shale is correlated with the whole or part of the upper limestone member of the Gasper.

(5.) Beneath the Renault in the Mississippi Valley is the Aux Vases sandstone, and beneath that the Ste. Genevieve limestone. That the top of the Ste. Genevieve here corresponds to some part of the Ohara member of the formation in western Kentucky is believed generally; and that this part is really "upper" Ohara is inferred from paleontologic evidence discussed in this work. In western Kentucky a sandstone agreeing in all essential respects with the Aux Vases occupies a similar position between the Renault equivalent in the Gasper limestone above and the Ohara member of the Ste. Genevieve below. This Kentucky sandstone, therefore, is referred to the same age and under the same name as the Aux Vases (=Bethel sandstone of Butts.)

(6.) The Chester series is naturally divisible into two groups or formations for which the terms Monte Sana and Birdsville as used by Ulrich in 1911 are here adopted. The rank of these divisions varies from region to region, being determined by local conditions which may or may not permit of more detailed subdivision. In the Appalachian and Allegheny plateau

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regions only two divisions of the series are practicable, and in these, therefore, the Monte Sana and Birdsville are formations. In western Kentucky and southern Illinois, and in the Mississippi Valley, however, the Monte Sana is divisible into three or more mappable formations, and the Birdsville into either eight, and possibly ten, alternating sandstone and limestone formations, or more naturally, as I believe, into four or five formations, each beginning with a sandstone and passing upward into a calcareous shale and limestone member.

The future classification of American stratigraphic units will be based on the natural relations of fully discriminated items of geologic time and events—both physical and organic; and these relations can be determined only by intensive correlation studies embracing the rocks and fossil faunas of the whole continent. Obviously, in working toward this desired end, all deterring artificial or local factors, such as the present dependence on priority of terms or practice and the precise limitations of original definitions of formations in any local sequence of deposits, must be subordinated to logical deductions and inferences drawn from facts which bear directly on the problems as a whole.

For instance, as in the case before us, the facts observable in either southwestern Illinois or in the Kentucky-Illinois fluorite district are not by themselves sufficient to insure a final classification of the upper Mississippian formations in either area. To attain this end our investigations must be extended so as to cover all areas in which deposits of similar ages have been laid down.

In this classification of the future, the upper Mississippian or Tennessean series of Ulrich will probably be ranked as a system comprising three co-ordinate series, the Meramec below, the Monte Sana in the middle, and the Birdsville above. Whether the latter divisions are recognized as series or groups, Worthen's term Chester group or series will have outlived its usefulness and necessarily become obsolete.

(7.) Marine sedimentation was not continuous through the Chester epoch. The process was interrupted at least five times before the final withdrawal of the Mississippian sea. Each interruption is marked by

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evidence of partial or complete withdrawal and more or less extensive shifting of seas. The first four of the submergent stages are shown in the paleogeographic maps. Comparison of these gives an idea of the kind of sea-shifting that accompanies these breaks in sedimentation. The succeeding Menard and Clore stages are insufficiently known to venture mapping their respective seas.

(8.) Western Kentucky and southern Illinois received deposits during all of the known submergent stages of the Chester epoch. Here also the section is more distinctly and more generally separable into the several stages than elsewhere, the calcareous closing facies of the deposit of each submergence being clearly distinguishable from the sandy introductory facies of the next succeeding submergence. For this reason the lower Ohio valley seems to provide a more desirable type or standard from which to work out the diastrophic history of the Chester epoch than either the Mississippi Valley proper or the Appalachian region. In other words, the sedimentary record of the Chester in southern Illinois and western Kentucky is more essential to a proper conception of Chester history than is that of either of the other regions. But none of them may be ignored if the conception is to be adequate. Localities in Alabama, for instance, may, and, as is shown in discussing the stratigraphy and faunas of the lower Chester formations in the vicinity of Huntsville, have supplied data that are absolutely essential to a true understanding of the section in the Mississippi Valley.

(9.) In a few places in the lower Ohio Valley, physical evidence of a small break within the Ohara member of the Ste. Genevieve is observable. Comparisons of many sections, however, show that these breaks are not of a kind affording a practical means of separating distinct lithologic or stratigraphic units. They do not occur at the same horizon in the several sections, and in most of the Ohara sections no satisfactory evidence of an important stratigraphic break is to be observed at all. Those that have been noted in the Ohara indicate merely local oscillations in a shallow sea. Oscillations comparable in areal extent and effect on deposition and

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faunas occurred repeatedly in all of the divisions of the Chester epoch.

(10.) The natural, and also the most practical because the most widely and most easily recognizable, basal boundary of the lower Chester or Monte Sana series is at the base of the Ste. Genevieve. Whether the problem is attacked from the stratigraphic, structural, or paleontologic side, the result in each line of inquiry agrees with this conclusion. Moreover, it agrees with the original determination and early practice of Hall, Worthen, Safford, and others. Worthen's subsequent different practice, especially in the Mississippi Valley, was occasioned by his misconception of the Ste. Genevieve limestone. He never believed in this formation as a separate stratigraphic unit; and he thought that Shumard's view of it was entirely in error. Certainly, Worthen never realized fully if at all that he himself, on the basis of fossil evidence, had referred equivalent deposits at Huntsville, Ala., to his Chester group.

(11.) In tracing the Ste. Genevieve and Gasper eastwardly from Caldwell County, the section loses first the Rosiclare sandstone and, soon after, the Aux Vases sandstone. The Ste. Genevieve also loses the shales and shaly limestones that make up the middle third or more of the Ohara member in Caldwell and Crittenden counties. With the Rosiclare sandstone absent and the Ohara practically all limestone, it becomes difficult to say how much of the Ste. Genevieve in, say Warren County, Ky., is of the age of the Ohara. And this difficulty persists through Tennessee and thence in Alabama to Tennessee River south of Huntsville. As the shales drop out of the Ohara, most of the decidedly Chesterian element of the Ohara fauna also fails, leaving little besides those persistent things that are as likely to be found in the Fredonia as in the Ohara member.

The lithologic as well as the faunal characters of the top beds of the eastern and southeastern representatives of the Ste. Genevieve being essentially the same as in the lower beds, paleontologists fell into the probable error of classing the whole as Fredonia, assuming, consequently, that the Ohara is wanting. But these assumptions are not warranted by any facts save contin-

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uity of lithologic features which, of course, imply continuity of conditions controlling the character of sedimentation; and continuity in the inferred character of bottom and other physical conditions naturally favored persistence of the Fredonia fauna and prevented the more characteristic Ohara species from gaining a foothold. Moreover, considerable fossil evidence is presented showing almost conclusively that the upper part of this continuous limestone facies of the Ste. Genevieve locally, as in the vicinity of Huntsville, Ala., and also near Waterloo, Ill., does contain fossil varieties that in Caldwell and Crittenden counties, Ky., and in Hardin County, Ill., have been found only in the upper Ohara. Besides, just before the shale of the Ohara and the Rosiclare sandstones passes entirely out of the section, as at Hopkinsville, the Ohara is still represented by at least 50 feet of limestone.

The Aux Vases sandstone pinches out eastwardly shortly after crossing the eastern border of Christian County. Thereafter the limestone of the Gasper is in contact with limestones of the Ste. Genevieve; and commonly it is not easy to determine exactly where the latter ceases and the former begins. It may be observed, for instance, that Mr. Butts in his columnar sections, Nos. 11, 13, and 15, shows no boundary between the two. Though a sharp boundary doubtless exists and might always be found if sufficient search were made, the fact remains that in a very large area it is impracticable to separate the two. Together they constitute the Monte Sana limestone. The reasons of convenience that induced the writer to propose this single term for the combined and practically inseparable Ste. Genevieve and Gasper limestones serve equally well in urging the inclusion of the whole and not merely the upper part of the Ste. Genevieve in the Monte Sana division of the Chester series as now understood.

(12.) In easterly* and southerly directions from Christian County, Ky., all of the sandstones of the Chester series, except the Cypress, pass out of the section which thereafter is composed entirely of limestone and

*This statement should be modified in that it does not apply to the northern portions of the belt of counties (Todd, Logan and Warren) lying east of Christian County. "Easterly and southerly directions from the southern part of Todd County" would be more strictly correct. J. B. H.

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more or less calcareous shale. The lower Chester (Monte Sana limestone) and the Cypress sandstone and Glen Dean limestone of the Birdsville or upper Chester doubtless extended uninterruptedly across the depressed median part of the Cincinnati axis in southern Kentucky and northern Tennessee. To the other formations of the Birdsville, however, this passage seems to have been closed by land connection between the Cincinnati and Nashville domes, sea connection between western Kentucky and eastern Tennessee being possible only around the southern extremity of the Cincinnati peninsula. This condition has made exact correlation of the Birdsville formations on both sides of the axis extremely difficult. At present they may be safely made only to the extent of determining the age of a given bed as falling within the limits of a particular formation in western Kentucky. But the top and bottom limits of the western formation in the eastern exposures may be left undecided.

(13.) No conclusive or even probable evidence of extensive removal of beds by surface erosion during any of the emergent stages of the Chester epoch, including the one between the Ste. Genevieve and the Aux Vases, has been observed. Oscillations, resulting in emergence and consequent erosion of the exposed surface of deposits previously laid down, doubtless occurred frequently during the course of the Chester age. But that the erosion in any case effected complete removal of thick sheets of limestone over wide areas, as for instance, the Ste. Genevieve limestone preceding or during the deposition of the succeeding Aux Vases sandstone, seems altogether improbable. Because the Ste. Genevieve and other Chester formations are locally or widely absent in areas that receive or retain other Chester deposits, it does not follow necessarily that these absences are due to removal by erosive processes. On the contrary, it is much more likely that they were caused mainly by warping of the sea bottom and of the surface of nearby lands which produced sea-shifting and consequent local or general interruption of deposition in one or more arms of the epicontinental sea. The removal of thick, horizontal sheets of limestone would have required much longer time than was available; and

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it would have been impossible without preliminary, vigorous, local attack by streams. If we consider the probable lowness and flatness of the lands, such active streams are hardly conceivable. At any rate, in the time available the degradation of the land could not have progressed through the coarse carving of the preliminary stages. So far as known the stratigraphic record of the Chester in the Mississippi Valley exhibits no evidence whatever of such relief. Something approaching it is indicated between the Chester and the Pennsylvanian, but within the Chester itself only a single, probable instance of stream erosion is known. This is suggested by the narrow deposit of presumably Tar Springs sandstone in the bluff at Chester, Ill., previously mentioned. On both sides of this and apparently everywhere else the intra-Chester contacts are approximately even.

Accordingly, the absence of the Ste. Genevieve limestone in places in the Mississippi Valley and elsewhere is believed to be occasioned mainly by corresponding restriction of its sea and consequent original absence of its beds; and the Renault overlap in the Mississippi Valley means no more than a slight east-west expansion —probably only local—of preceding stages of the Chester sea. The Renault overlap occurred in the early part of the same age (Gasper), in the later part of which the much more extensive Maxville limestone transgression occurred. The Chester sea in this age extended northward from western Kentucky through Indiana into Michigan, and from eastern Kentucky into Ohio and Pennsylvania. At the same time also it stretched westward from the lower Mississippi Valley to southwestern Missouri and northwestern Arkansas. The later Gasper transgression thus covered large areas not previously reached by Chester seas. In other places, however, where the Gasper is in contact with the Ste. Genevieve—therefore without the elsewhere intervening sandstone (Aux Vases) between them—the contact exhibits practically no clear indication of long-enduring emergence and subaerial erosion. Hence, arguing from the total evidence now in hand, none of the three or four local unconformities in the Ste. Genevieve limestone seems to be of the grade of importance demanded by a major stratigraphic boundary.

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(14.) In contrast to the preceding, long-continued emergence and considerable erosion of the top of the St. Louis limestone is *plainly* indicated wherever the contact between this limestone and the succeeding Ste. Genevieve limestone is clearly exposed. In places in the Appalachian region the St. Louis is entirely missing. In other places, as shown in photographs taken near Jasper, Tenn., mere remnants, with strongly undulating upper surfaces, remain. Locally in the Mississippi Valley, as at Ste. Genevieve, Mo., the surface of the St. Louis shows deep fissures which were filled with land sweepings containing pebbles of various kinds before the re-advancing Ste. Genevieve sea resumed normal marine deposition.

(15.) The lithologic sequence in southwestern Illinois, beginning with a formation that consists mainly of limestone and which was distinguished by Weller under the term Renault formation, then a quartzitic or cherty bed to which he gave the name Yankeetown chert, and this followed by another association of limestone and calcareous shale known as the Paint Creek formation, is much more closely paralleled in the lithologically tripartite Gasper limestone, as developed in Breckinridge and adjoining counties in Kentucky, than in the "upper Ohara"—so-called Bethel (Aux Vases) sandstone—Ridenhower shale sequence found in Crittenden County, Ky., and Pope County, Ill. In Breckinridge County the Gasper consists of a lower and an upper limestone with a sandstone—the Sample—up to 40 feet in thickness between them. The upper of these limestones passes westwardly into the Ridenhower shale, and the Ridenhower, as all believe, represents the Paint Creek formation. The lower limestone of the Gasper, however, pinches out entirely before reaching Crittenden County, but in tracing it westwardly from Breckinridge to Christian and Caldwell counties a thick wedge of sandstone is found to enter the section so as to separate the base of the lower Gasper limestone from the top of the subjacent Ohara member of the Ste. Genevieve limestone. Now, this dividing sandstone is in every respect precisely like the Aux Vases sandstone which *underlies* the Renault in Randolph County, Ill. Furthermore, in the adjoining county of Monroe the Aux Vases is *underlain*

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by the typical Ste. Genevieve limestone, the upper part of which is separated from the more oolitic lower part by a calcareous sandstone exactly like the Rosiclare sandstone. The sequence of the beds of the Ste. Genevieve therefore is essentially the same here as in western Kentucky. Moreover, the upper member of the Ste. Genevieve in the Mississippi Valley is correlated on incontestable fossil evidence with the Ohara member of the formation in western Kentucky and southern Illinois. Finally, as the lower and upper limestones of the Gasper are characterized by fossil faunas that are respectively precisely identifiable with the faunas of the Renault and the Paint Creek, it follows that the Ohara can not correspond with the Renault. On the contrary, the sum total of the abundant evidence in hand unqualifiedly demands the correlation of the Renault with the lower Gasper. These conclusions at the same time remove all reasonable obstacles to the acceptance of the term Aux Vases for the sandstone lying between the Ohara and the Gasper.

Weller's correlation of the Renault with the upper Ohara is not only opposed by all positive correlation criteria but requires the unwarranted assumption of absence of certain formations in the affected areas. Thus, the sandstone between the Ohara and the lower Gasper that is here recognized as the Aux Vases must, under his interpretation, be correlated with the Yankeetown chert, a bed that is not only very different lithologically but wholly absent over most of the area between Union and Monroe counties. As for the Aux Vases sandstone, Weller says that it is absent south of Randolph County, and that its unoccupied position in the sections beginning with Union County and extending thence to central Kentucky and far beyond is marked by a stratigraphic break. But these are pure assumptions, without direct basis in fact, to which he has been driven by his correlation of the upper Ohara with the Renault. In the view here defended the Aux Vases stretches practically without interruption from Monroe County, Ill., to Todd County, Ky.; and the supposedly important break in the Ohara resolves itself into local manifestations of a series of minor oscillations that here and there caused brief interruptions of the progress of Ohara deposition.

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PALEONTOLOGIC PART.

(1.) Under the heading, Modern requirements in correlating by fossil faunas, the author deprecates the too common practice of correlating formations by generalized faunal agreement or by identification of loosely conceived species. The incompetence, or at least inconclusiveness, of arguments favoring exact correlation by such inadequate means is clearly established by an almost continuous trail of errors directly chargeable to them. In this day of progress by refinement and correction of methods, the hope that this protest against the use of long and abundantly discredited means of correlation may prevail seems better warranted than heretofore.

Before arguments based on identifications of fossils and faunas may be accepted as valid, not to say incontrovertible, it should be clear that the author has exhausted all means of arriving at a satisfactory conclusion—among them in this case, that he has critically studied not only the upper Ohara fossils of the Kentucky region, but similarly complete collections from the underlying Fredonia and the overlying members of the Gasper in the same region. We must feel assured, further, that his collections have been made with due regard to the stratigraphy. Also that he has studied at least certain classes of his material sufficiently to be able to discriminate and recognize the minutely indicated mutations that distinguish the correspondingly minor stages in the evolutional history of all complexly organized animals. From the standpoint of stratigraphic correlation it is absolutely necessary to discriminate these biologically perhaps unimportant mutations, because they afford the only inherently competent means of exactly correlating stratigraphic horizons and geological dates.

In accord with this principle the stratigraphic or correlation value of a fossil is in direct proportion to its relative complexity of structure. If the features for comparison are many and definitely determinable, the indexical value of the fossil is correspondingly great; if the structure is simple and comparable features limited in number and not readily determinable, the use-

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fulness of the fossil in stratigraphic correlation is correspondingly inferior.

(2.) A fauna of 155 species is listed from the Fredonia oolite member of the Ste. Genevieve limestone in Caldwell and Crittenden counties, Ky. Of these only 16 species are common to underlying formations of the Meramec series (Warsaw, Spergen, and St. Louis), and of the 16 all but one pass upward into the Gasper. All the other species (139) are met with for the first time in the Fredonia.

The faunal relations of the Fredonia to the overlying upper Ohara and again to the Gasper are much stronger. Thus, 54 species, or more than half of the total fauna of 93 species listed from the Ohara in Caldwell and Crittenden counties, have been found also in the Fredonia member. Moreover, all of these species occur in the Ohara above the very locally developed intraformational conglomerate which in such places marks the introduction of a number of well-known Chester fossils. But with them are many equally characteristic Chester species whose first appearance in western Kentucky occurred already in the Fredonia member of the Ste. Genevieve.

The closeness of the relation between the Fredonia and the upper Gasper faunas is shown by the fact that 56 of the Fredonia species are identified also in the faunas of the upper Gasper, the transgressing species constituting approximately a third of the latter fauna. These facts warrant, so far as generalized paleontologic data may do so, the author's practice of uniting the whole of the Ste. Genevieve together with the overlying Aux Vases sandstone and the Gasper limestone in a group (Monte Sana) of the Chester series, instead of dividing, as Professor Weller proposes, the Ohara member of the Ste. Genevieve at some commonly undeterminable plane into an upper part which he refers to the Chester series, and a lower part which he refers together with the underlying Rosiclare and Fredonia members to the top of the Meramec series or to a far from co-ordinate immediate series.

(3.) Of great importance in determining the systematic relations of the Fredonia and Ohara members is the fact that of such complicated and minutely dis-

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criminated fossils as the four species of Pentremites listed as occurring in the Fredonia, all ranged without appreciable change into the upper Ohara. If we consider this fact in connection with two other facts, namely: (1) that all of the Fredonia *Pentremites* are easily distinguishable from the known Meramec species; and, (2) that none of the 8 species and varieties of this genus that are found in the upper Ohara beds in western Kentucky is exactly like any of the 37 species and varieties found in the upper Gasper limestone nor precisely like any of the 5 species found in typical Renault exposures in the Mississippi Valley, it seems impossible to avoid the dual conclusion that whereas the upper Ohara and the Fredonia pentremital faunas are essentially a unit, the Ohara, the Gasper, and the Renault pentremital faunas are wholly distinct. Consequently, on the basis of the *Pentremites*, correlation of the upper Ohara with the Renault is definitely negatived.

(4.) The Fredonia member of the Ste. Genevieve contains a large number (at least 50 species) of Bryozoa, Brachiopoda, and other classes of fossils that are commonly and so far as known correctly regarded as diagnostic of the Chester age. Among these the brachiopods *Diaphragmus montesana* (*D. elegans* part of authors), *Productus arkansanus,* and *Productus inflatus* are regarded by some paleontologists as particularly trustworthy. In the writer's estimation, however, the correlation value of either of these brachiopods is no greater than that of any one of the many other "Chester" fossils found in the Fredonia. Giving all of them due consideration, their combined testimony is so strong as to make the Fredonia indisputably Chester, or at least lower Chester.

(5.) An important feature of the evidence showing the close paleontological affiliation of the upper Ohara and the Fredonia is the occurrence in the former at Princeton and other localities in western Kentucky of at least five crinoids, among them *Platycrinus huntsvillae,* that commonly but mistakenly have been supposed to be confined to Ste. Genevieve beds beneath the upper Ohara.

(6.) Six or seven species of crinoids, including

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Platycrinus huntsvillae in extraordinary abundance and at least two other species found in Kentucky only in the upper Ohara, have been found in the upper part of the Ste. Genevieve limestone near Huntsville, Ala. It seems likely, therefore, that this upper *Platycrinus* bed at Huntsville is of the age of the upper Ohara in western Kentucky. Most of these Alabama crinoids, and with two or three somewhat doubtful exceptions all of them, have been found also in the upper part of the Ste. Genevieve limestone near Waterloo, Ill. Judging from these crinoids the upper Ohara seems to be represented in the crinoid bed in Illinois as well as in Alabama and Kentucky. It seems worth remembering, too, that four of these species were originally assigned by Hall, and presumably also by Worthen who collected them at the Waterloo locality, to the "Kaskaskia" limestone.

Another crinoid that indicates the presence of upper Ohara beds in the typical Ste. Genevieve limestone is the peculiar and altogether unmistakable *Batocrinus* (or *Dizygocrinus*) *unionensis*. This species was described and found by Worthen in the Ste. Genevieve or, as he called it, the "St. Louis" limestone, near Anna, Ill. Absolutely indistinguishable specimens of this crinoid are found in zone 3 of the Ohara in the lower Ohio Valley. It is not uncommon in the vicinity of Rosiclare, Ill., where it occurs in the highly fossiliferous bed of shale that represents zone 3 and here lies immediately above one of the local unconformities that in some places separate the "upper Ohara" from a lower division of the Ohara member.

(7.) At Waterloo, Ill., Huntsville, Ala., and in western Kentucky this upper Ste. Genevieve crinoid bed contains four species of Batocrinidae and one or two species of *Platycrinus*. Both of these types are of very large families, of cosmopolitan distribution, and of extraordinary specific and individual development during preceding Mississippian ages. Although many crinoids are known from Chester deposits, neither of the two families mentioned is represented, excepting one doubtful instance, among the species found in the Renault formation or in other Chester formations of later ages than the Ste. Genevieve. This is strong negative evidence against the claim made by Weller that the upper

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Ohara, in which both Platycrinidae and Batocrinidae are found, is to be correlated with the Renault. The strength of this evidence becomes particularly impressive when it is considered in connection with the fact that the crinoid fauna of not only the upper Ste. Genevieve but also of the succeeding Renault-lower Gasper crinoidal zone at these two widely separated places is in both cases perfectly comparable. In fact, according to Mr. Frank Springer, no less than nine of the dozen or more Renault crinoids, excluding those of the genus *Talarocrinus,* are found also in the lower Gasper horizon near Huntsville, Ala. Some of these crinoids, Mr. Springer points out, are "highly specialized forms and therefore uncommonly valuable for correlation purposes."

(8.) Very few fossils of restricted range are common to the Ohara member of the Ste. Genevieve and the Renault formation; and most of those that have been identified in these two formations are either not strictly the same or they are not particularly characteristic. The presence of *Lyropora* in the uppermost bed of the Ohara does not make this zone of Renault age, because the species are distinct. And it is the same with *Talarocrinus,* the three species of this genus in the Ohara being different from those found in the Renault. Nor are the *Pentremites* the same. On the other hand, the oftenmentioned *Talarocrinus ovatus* which was described by Worthen from Renault specimens occurs in Kentucky only in the lower division of the Gasper. Similarly, of three other species of this genus found in association with *T. ovatus* in the typical Renault, two, namely, *T. symmatricus* (Lyon and Casseday) and *T. delicatus* Springer MS., likewise have been found in Kentucky only in the lower Gasper.

Further positive evidence of the equivalence of the Renault formation of Monroe and Randolph counties in Illinois to the upper part of the Gasper limestone in Kentucky, Tennessee, and Alabama is found in the fact that the five species of *Pentremites* which have been collected from the Renault crinoid bed, near Waterloo, Ill., are found also in the lower limestone of the Gasper.

(9.) A fact of great significance is the similarity in the direct sequence of identical Ste. Genevieve and

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Renault crinoid and blastoid faunas of two such widely separated localities as Huntsville, Ala., and Monroe County, Ill. This concordance in sequence is rendered all the more striking by the fact that in both places the two superposed crinoidal faunas contain the same three species in common. However, the complete significance of these facts will be appreciated only when it is recalled that at Huntsville the lower of the two horizons contains an abundance of *Platycrinus* and species of Batocrinidae, together with many *Pentremites* and other fossils, the whole making an association that can be matched only in the upper Ohara of western Kentucky. It follows, therefore, if this lower *Platycrinus*-containing zone is, as it seems to be, upper Ohara, then the upper Ohara can not be of the age of the Renault.

(10.) On the basis of many closely discriminated and in part highly specialized fossils held in common, the Paint Creek formation of southwestern Illinois is correlated with the whole or a part of the upper Gasper of Kentucky. That the relations of the Paint Creek formation to the Renault formation are comparable to those obtaining between the upper and the lower divisions of the Gasper limestone in Kentucky is indicated primarily by the fact that in both states the *Pentremites* of the lower units continue upward without appreciable modification into the upper units, that is, from the Renault to the Paint Creek in the one area, and from the lower to the upper division of the Gasper in the other. The differences between the complete lists of the Paint Creek and the Renault faunas on the one hand, and between the lower and the upper Gasper faunas on the other, are not indicative of long time but rather rapidly executed changes in faunal supply and migration. Despite changes in environment the species that survived suffered little or no appreciable modification whatever. But the composition of the fauna as a whole changed very greatly in the Paint Creek and upper Gasper through the introduction or recurrence of types that were absent in the earlier lower Gasper-Renault stage, and the final or local extinction of others that thrived in the Renault stage.

(11.) The rather strong development of the genus *Talarocrinus* in the upper Ohara and the Renault has

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been cited in confirmation of two of Weller's views that differ from those of the writer: (1) that it supports Weller's correlation of the upper Ohara with the Renault; and, (2) that it indicates a sufficiently well-marked faunal change to exclude the beds beneath the upper Ohara from the Chester series. But neither of these claims is tenable. The first is invalidated by the fact that the Ohara species of *Talarocrinus* are clearly different from those found in the Renault. On the other hand, three of the four Renault species of this genus are found in Kentucky in the lower member of the Gasper limestone. The second fails because the genus was not introduced in the Ohara but had been differentiated from the earlier *Dichocrinus* already in the age of the Spergen oolite. Abundant experience has shown that it is never safe to assume restriction of any vigorous generic stock to a stratigraphic unit of the grade of a formation, group, or series. In the present instance all we are warranted in saying of the stratigraphic occurrence of *Talarocrinus* is that the genus attained its greatest known individual and specific expansion during the time in which the Ohara and the lower Gasper or Renault deposits were laid down in southeastern America. Its preceding and succeeding history is of course much less well known. Therefore, and the same is true of all other fossil generic types, the known apparent expansion of *Talarocrinus* in the middle beds of the Monte Sana group is a mere incident in a continuous process of organic development. Besides, to Shumard, Lyon, and Wachsmuth and Springer the crinoidal type now known as *Talarocrinus* was pre-eminently a St. Louis fossil. It is only now that we are learning that the species described by the authors mentioned are not of St. Louis but of Gasper and, at that, chiefly of lower Gasper age. Accordingly then, the use of these fossils in stratigraphy is mainly in the identification of the several species which then helps in correlating the particular beds in which they are found. But, taking the genus as a whole or considering only its stage of highest development, neither should be accorded any greater significance in fixing the position of an important stratigraphic boundary than is given to hundreds of fossil genera that similarly and in many instances more fully

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transgress boundaries separating units of the grade of groups, series, and even epochs. It might be temporarily convenient, but it is most certainly not condusive to the winning of the truth.

(12.) The practical absence of Bryozoa, particularly of the genus *Archimedes*, in the lower member of the Gasper limestone and their contrasting abundance in the middle and upper divisions is especially noteworthy, because a similar distribution of these same specifically identified organisms obtains also in the respectively correlated Renault, Yankeetown, and Paint Creek formations in Illinois.

(13.) Out of a total Renault fauna of about 35 species, 23 have been identified in the lower Gasper in Kentucky and Alabama; and 9 of these are unknown in any other stratigraphic position. The remaining species are either confined to the Renault in Illinois or of known longer range in Illinois and elsewhere. Most of the latter range up from below and pass on into higher Chester beds; or they are common to only the Renault and the Paint Creek in Illinois, and similarly to the upper as well as the lower division of the Gasper in Kentucky and Alabama.

Out of a total Paint Creek fauna of approximately 50 species, 42 are found also in the middle and upper members of the Gasper south of the Ohio. More than half of these species do not occur in the Renault in Illinois nor in the lower Gasper of Kentucky, Tennessee, and Alabama.

None of the species that are really characteristic of the Renault in Illinois and of the lower Gasper in Kentucky and Alabama is found in the Ohara in Kentucky. Similarly, none of the species that are confined to the Ohara in Kentucky is known to occur in the Renault.

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PALEOGEOGRAPHIC CONSIDERATIONS.

The Mississippian sea advanced and retreated many times in the great area now included in the east central states. The particular geographic pattern that characterizes each of the successive submergent stages is determined with reasonable definiteness by various corroborating and accessory means, the most important of which is the present distribution of particular fossil faunas. But if the map is to be of any value at all, we must be sure that the correlated faunal units are really of the same age and not merely similar in general aspect. The emergent stages are less easily determined, particularly as regards the extent of the retreat of the sea in any given instance. A stratigraphic break in a series of marine deposits with indications of land conditions is, of course, the main and perhaps the only really competent part of the evidence on which sea retreat may be inferred. But this most desirable kind of testimony, even when the concerned plane is at the surface, is often obscured or quite concealed by the residual mantle of decomposed rocks. A yet more important break, in that it concerns especially the extent of sea-withdrawal, is the fact that the median and deeper parts of the invaded continental basins are inaccessibly buried beneath subsequent marine and land deposits. But, despite these common handicaps, deep wells and other means give information by which even the emergent stages may often be deciphered with some claim to approximate accuracy; and this, after all, is as far as we may hope to succeed in reproducing the geographic patterns of past geologic ages.

Stratigraphic boundaries of high systematic import commonly are indicated by decided contemporaneous changes in the sequence of paleogeographic patterns. This is so because both the stratigraphic boundaries and the shifting of the seas are occasioned by and consequent to diastrophic differential movements of the lithosphere. These movements made new depressions in the surface of the continents only at long intervals. Between these intervals they effected countless changes in the way of modifying pre-existing structures, one or more basins being partly or wholly elevated above sea

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level while others were more deeply submerged, and yet others resubmerged after some long or relatively short period of local emergence. As a rule, however, these minor shiftings of the sea, providing the oceanic connection remains the same, do not greatly transgress the outline of a fairly definite general pattern that covers all the stages in any particular epoch. The composite Chester maps illustrate this principle very well.

Some geologists are reported as doubting that the Ste. Genevieve stage harmonizes as well with the composite Chester pattern as with the preceding Meramec. But really, with the exception of the Des Moines bay in which it somewhat obscurely inherits a late Meramec characteristic, the Ste. Genevieve harmonizes very well indeed with the Chester scheme. Besides, it is no more like the St. Louis pattern than is the upper Gasper stage. The St. Louis stage differs materially from both of these early Chester stages in wanting the Arkansas bay and in the broader outline of its northern shore in Missouri, Iowa, Illinois, Indiana, Michigan, and Kentucky. There was less relief to the lands bordering it and consequently less of detail in its shore line. The complications in these respects which distinguish the stages of the Chester epoch from those of the Meramec began with the Ste. Genevieve and became progressively greater to the close of the Tennessean period. The St. Louis sea was broad, fairly deep, and evidently passed over the Nashville dome; the Ste. Genevieve sea was much shallower and almost certainly did not submerge the Nashville dome. The Ste. Genevieve introduced the Monte Sana in much the same way as the Warsaw-Spergen introduced the Meramec and the Okaw introduced the Birdsville. The differences between the three sequences are but the natural consequences of the progressively manifested tendency to complete continental emergence that culminated in the long-enduring post-Tennessean land dominance.

Evidently paleogeographic studies lead to the same conclusions regarding the classification of the Ste. Genevieve limestone as do all the other lines of evidence, namely, that the Ste. Genevieve is properly included in the lower Chester or Monte Sana series.

All verified means of correlating stratigraphic hori-

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zons—including the physical criteria as well as the organic—have been employed in determining the sequence and time relations of the lower Chester or Monte Sana group of formations in eastern United States. The result in each and every trial proved definitely favorable to the views here advocated. Such corroborating uniformity in the trend of all kinds of evidence would be impossible if the conclusions reached were not true in all essential respects.

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FAUNAS OF THE UPPER CHESTER OR BIRDSVILLE GROUP.

Although the fossils collected from the higher formations of the Chester series in western Kentucky in 1888-1890 were as carefully studied at that time as those procured during the same period from the lower beds of the series, time is lacking on the present occasion to revise their early determination as fully as I desire. The following lists, therefore, are presented with less confidence in their accuracy than the preceding ones. Still, whatever apologies may be called for when the material is subjected to final investigation, I feel assured that such occasions will be almost confined to the Brachiopoda. Regarding the other classes, the few trilobites, the Cephalopoda, and the more numerous Ostracoda were almost ignored, but the work on the Pelecypoda, Gastropoda, Crinoidea, and Bryozoa was brought to a stage that has not been materially improved either by others or by myself in the past 25 years. Moreover, one important group of Chester fossils—the Pentremites—has been exhaustively studied in the past few months. Among the last are some excellent stratigraphic guides. The best and most widely distributed of these are illustrated on the plates of guide fossils.

As practical unanimity of opinion regarding the correlation of most of the Birdsville formations in Kentucky and Illinois exists among the geologists who have studied these formations in the past few decades, there is little and probably no sufficient reason for such detailed discussions of these faunas as seemed desirable in the case of the lower Chester fossils. Accordingly, this part of the paper is made as brief as possible without making the contrast in treatment unduly great.

FOSSILS OF THE GOLCONDA FORMATION.

GENERAL DISCUSSION.—The Golconda formation contains a considerable fossil fauna wherever it has been definitely recognized in the western half of Kentucky and in southern Illinois. Fossils are particularly abundant and readily procurable in those parts of the formation that are made up of thin alternating layers of calcareous shale and limestone. The heavier limestones,

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referring particularly to those near the top of the formation, also contain fossils, but as a rule these are neither good nor readily extractable. They occur also in the shales, especially in the basal part of the formation. However, on account of the friable nature of the matrix, collections can be made from these shales only when freshly exposed.

Judging from sections in Illinois and Kentucky and comparisons of fossil faunas found in the Randolph County basin to the northwest, and in eastern Kentucky, Tennessee and Alabama to the east and southeast, both the Golconda formation and its fauna seem to be confined to areas lying to the west of the Cincinnati axis. That the formation does pinch out in part or whole by overlap in both the directions mentioned is indicated: (1) as shown in Mr. Butts's sections, by decrease in thickness from approximately 140 feet on the Ohio at Golconda, Ill., to 30 feet or less in the southern part of Breckinridge County; and, (2) by the complete absence of all the characteristic Golconda species in the Randolph County area. Other data bearing on this matter have been discussed on previous pages.

As the most characteristic species of the Golconda occur, so far as known, only in its lower half, I hesitate somewhat to say that the entire thickness of the formation—referring, however, only to that part of its extent which lies to the north of central Tennessee—is confined to the lower Ohio basin. Nevertheless, I believe this to be so, because certain varieties of common Birdsville species of *Pentremites* and *Archimedes* found plentifully in the upper part of the Golconda in Livingston County and elsewhere in Kentucky and in southern Illinois have not been observed in either direction beyond the area to which the formation is supposed to be limited. In view of the fact that beds similar in character to those that contain these peculiar varieties in Livingston County are found in both directions beyond the assumed limits, their absence in the latter might well be accepted as establishing the suggested complete outlap of the formation. But this interpretation does not exclude a short Appalachian arm of the Golconda sea that is strongly suggested by fossiliferous limestones

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and shales in northeastern Alabama and adjacent parts of Georgia and Tennessee.

ZONES AND LOCALITIES FROM WHICH LISTED FOSSILS WERE COLLECTED.—The following list of 90 or more species is a composite made up of collections found at three localities in Kentucky. The first of these contains 43 species embedded in dark shale and thin slabs of limestone thrown out of a shallow well in the eastern part of Marion, in Crittenden County. The beds containing these fossils are supposed to belong in the lower 30 feet or so of the formation. The species found here are marked in the first column to the right of the list. As may be seen, this collection differs from the others in consisting almost to one-half of Pelecypoda.

The second locality is on Champion Hill, in Livingston County, 3 to 4 miles west of Salem. The top of the hill is formed of Hardinsburg sandstone of which a thickness of 75 feet or more is retained. Beneath this about 70 feet of the upper part of the Golconda is exposed to the fault at the cemetery. The lower 25 feet of this consists mainly of soft, green shale with very few fossils. This is succeeded by several feet of crinoidal limestone, then 8 feet or so of shale containing an abundance of *Archimedes* and plates of *Pterocrinus capitalis*, and this by 3 feet of thin limestones and shale in which the shells of Pelecypoda and imperfect calyces of *Eupachycrinus* are notably plentiful. The last is followed by about 20 feet of soft, green and purplish, unfossiliferous shale, and finally by 5 or 6 feet of earthy limestone containing imperfect remains of a large *Pentremites* somewhat doubtfully referred to *Pentremites obesus*. The fossils procured from this locality comprise 47 species as indicated in the second column.

The third locality is in eastern Caldwell County, in a cut along Illinois Central Railroad, about 1 mile west of Claxton Station. Some 45 to 50 feet of limestone interbedded with shale, strongly dipping toward the east, is shown here. Good fossils are few in these beds, except in a layer of calcareous shale about 2 feet thick toward the top of the exposure. This is filled with excellent brachiopods and Bryozoa, these and other species

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found here being indicated by an x in the third column. Beneath the limestones at this locality is a shaly sandstone—possibly the top bed of the Cypress sandstone of which an unusual thickness is exposed in the next cut to the west. It seems more probable though that the limestone here is the upper bed of the formation and that the lower beds are represented here by sandstone and shale.

Comparison of the fossils from these three localities shows decided differences in their respective faunas. These differences are particularly notable in comparing the general aspect of the several collections. Thus, in the first the Pelecypods are predominant, in the second the *Archimedes* and thick plates of *Pterocrinus capitalis* and *Eupachycrinus* aff. *boydi* are most prominent, and in the third the shells of spire-bearing brachiopods constitute the bulk of the collection. Apparently the composition of the Golconda fauna varied greatly from time to time and from place to place.

Another faunal zone occurs in Crittenden County, Ky., and Pope County, Ill. This lies something like 75 to 100 feet beneath the top of the formation. As a rule it is largely composed of limestone in which the separated plates or more or less nearly complete heads of a large *Pentremites*—*Pentremites obesus*—are locally very abundant. Positively identifiable specimens of this species, so far as known, have been found only in this zone. However, fragments suggesting the same species have been observed in higher beds; and a few good specimens that were collected by Lyon in Grayson County also tend to show that the species is not confined to the zone in which it is most commonly seen in the western counties. Whatever its vertical range may finally prove to be, the species as now known must be counted a rare fossil east of Crittenden County. Even there good heads have been observed reasonably abundant only on the east slope of Pickering Hill, north of Marion.

Unfortunately no separate list of the fossils found with *Pentremites obesus* on Pickering Hill was prepared; and as the specimens have been distributed according to their biological relations, the trouble of reassembling them seemed too great and the probable result too uncertain to repay the effort.

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Composite List of Fossils Found in the Golconda Formation in Livingston, Crittenden and Caldwell Counties.

		Marion	Champion Hill	Caldwell County
1.	Hindia? (n. gen. with spicular columns very small)		X	
2.	Zaphrentis spinulifera		X	
3.*	Pterotocrinus capitalis		X	
4.	Pterotocrinus coronarius		X	
5.*	Pterotocrinus n. sp. 1 (related to P. depressus)		X	
6.	Pterotocrinus? n. sp. 2 (perhaps the same as first species of the genus listed in the Gasper fauna)		X	
7.	Pachylocrinus cf. bayensis		X	
8.	Eupachycrinus? sp. 1	X		
9.*	Eupachycrinus cf. boydi		X	
10.*	Pentremites obesus?	?	X	
11.	Pentremites cf. spicatus (Ulrich n. sp.)			X
12.	Pentremites cf. pyramidatus		X	
13.	Pentremites cf. canalis (Ulrich n. sp.)		X	
14.	Spirorbis sp.		X	
15.	Hederella sp.		X	
16.	Stenopora tuberculata	X	X	X
17.	Stenopora cestriensis		X	
18.	Batostomella abrupta	X		
19.	Batostomella spinulosa			X
20.	Batostomella sp.			X
21.	Lioclema araneum	X		X
22.	Fistulipora sp. 1			X
23.	Fistulipora sp. 2			X
24.	New genus Fistuliporidae, with hollow, ramose stems			X
25.	Proutella n. sp.			X
26.	Rhombopora (Orthopora) persimilis		X	X
27.	Rhombopora (Orthopora) pulchella			X
28.	Rhombopora minor		X	
29.	Rhombopora armata		X	?
30.	Streblotrypa nicklesi		X	
31.	Streblotrypa n. sp. (aff. S. subspinosa)	X		
32.	Cystodictya aff. pustulosa		X	
33.	Prismopora aff. minima (small, edges straight)			X
34.	Fenestella serratula	X	X	X
35.	Fenestella tenax	X	X	X
36.	Fenestella cestriensis	X	X	X

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Composite List of Fossils Found in the Golconda Formation in Livingston, Crittenden and Caldwell Counties—Continued.

		Marion	Champion Hill	Caldwell County
37.	Polypora corticosa		X	X
38.	Polypora cf. approximata			X
39.	Thamniscus furcillatus			X
40.	Archimedes cf. communis		X	
41.	Archimedes compactus		X	
42.	Archimedes intermedius		X	
43.	Archimedes meekamus	X		
44.	Archimedes swallovanus		X	
45.	Archimedes swallovanus var. or n. sp.		X	
46.*	Archimedes lativolvis		X	
47.	Archimedes terebriformis?		X	
48.	Archimedes n. sp.		X	
49.	Septopora sp.		X	
50.	Crania sp.			X
51.	Orthothetes kaskaskiensis		X	X
52.	Productus scabriculus?	X	X	
53.	Productus sp.?	X		
54.	Productus sp.?		X	
55.	Spirifer cf. increbescens (long-hinged form)			X
56.	Spirifer aff. increbescens (shell thin)		X	X
57.	Spirifer cf. breckinridgensis	X		
58.	Spirifer cf. leidyi		X	
59.	Spiriferina transversa		X	X
60.	Spiriferina spinosa		X	X
61.	Spiriferina spinosa var. (plications subangular)	X		
62.	Eumetria vera	X		X
63.	Composita subquadrata	X	X	X
64.	Cliothyridina sublamellosa		X	
65.*	Aviculopecten sp. 1 (large, with strong radiating ribs)	X	X	
66.*	Aviculopecten sp. 2 (smaller than sp. 1, with fine radiae and strong fold on anterior ear)	X		
67.	Aviculopecten sp. 3 (or var. of sp. 2 without fold on ear)	X		
68.	Aviculopecten sp. 4 (small, without radiae but with exceedingly fine concentric ribs)	X		
69.	Aviculopecten sp. 5 (small, with strong spinose radiae)	X		

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Composite List of Fossils Found in the Golconda Formation in Livingston, Crittenden and Caldwell Counties—Continued.

	Marion	Champion Hill	Caldwell County
70. Monotis? sp. (small shell, without ears, surface finely striated radially)	X		
71. Pteronites aff. spergenensis	X		
72. Myalina sp.	X		
73. Parallelodon cf. illinoiensis	X		
74. Cypricardinia cf. indianensis	X		
75. Clinopistha? sp. (has very small radially arranged surface granulation)	X		
76.* Leda sp.	X	X	
77. Nucula sp. 1	X		
78. Nucula sp. 2	X		
79. Nucula sp. 3		X	
80. Solenomya n. sp.	X		
81. Cardiomorpha? n. sp.	X		
82. Modiola? sp. 1	X		
83. Modiola? sp. 2	X		
84. Schizodus sp. 1 (large ovate shell without umbonal ridge)	X	X	
85. Schizodus sp. 2 (smaller, with low umbonal ridge)	X		
86. Pleurotomaria sp. 1	X		
87. Pleurotomaria sp. 2	X		
88. Euomphalus similis	X		
89. Lævidentalium cf. venustum	X		
90. Orthoceras sp. 1 (rather large annulated species)	X		
91. Orthoceras sp. 2 (smaller, simple form)	X		
92. Conularia chesterensis	X	X	
93-98. Ostracoda—at least 6 species, all undetermined	X		
99. Phillipsia sp.	X		

Species marked with an asterisk (*) are regarded as particularly characteristic of the formation.

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Taken as a whole, the fauna of the Golconda as above listed resembles that of the Gasper and the lower Ste. Genevieve perhaps as much as that of the succeeding Glen Dean limestone. However, when the indicated alliances are more closely analyzed we find that the relations to the older faunas are chiefly among those species that have their nearest allies in preceding facies of the Spergen fauna. The mollusks, particularly, look old. The Bryozoa, with a few notable exceptions, are simply Chester forms with little or no preference toward either their ancestors or their descendants. But there need be no doubt regarding the direction of the slant when we compare the *Pentremites* and crinoids. These, when compared with the Gasper forms on the one hand and the Glen Dean species on the other lean decidedly toward the latter.

Because of its bearing on the suggestion that the Cypress rather than the Golconda corresponds in age to the lower two-thirds of the Okaw limestone, it is important to note that the *Pentremites* of the Golconda formation indicate an intermediate stage in development between that shown by those found in the Okaw and those in the Glen Dean. Regarding *Pentremites obesus,* for instance, it is undecided whether it is nearer *Pentremites chesterensis,* an Okaw limestone species, or *Pentremites robustus,* a Glen Dean fossil. And similar relations are exhibited by Okaw, Golconda, and Glen Dean species and varieties derived from *Pentremites godoni,* the typical form of which is confined to the Gasper oolite in the south and to its correlates in western Illinois.

Those species of the list that experience to date sets apart from the rest as having the greatest practical value as guide fossils are prefixed by an asterisk. The discovery of any one, or preferably two or more of these should suffice to fix the age of the containing rock as that of the Golconda formation.

FOSSILS OF THE GLEN DEAN LIMESTONE.

Considering only the quantity and both vertical and areal distribution of its fossils. the Glen Dean limestone is the most fossiliferous formation of the Chester series.

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In number of species also this fauna may exceed all the others, but in the matter of variety it is inferior to that of the Golconda, the Gasper, or the Ste. Genevieve. Except the ubiquitous *Zaphrentis spinulifera,* corals are practically wanting in the Glen Dean. The mollusks are also very poorly represented; and the same is to be said of the trilobites and less positively also of the ostracods. The brachiopods, however, are fairly abundant. Indeed, in certain beds these shells constitute the most conspicuous part of the fauna. Still, viewed as a whole, the Glen Dean fauna is pre-eminently one of Bryozoa, Pentremites, and Crinoidea. Good to excellent specimens of the Bryozoa may be found in most parts of the formation, but they are most abundant in the shaly limestones. The *Pentremites,* too, are commonly present and nearly as abundant in the solid limestones as in the shaly beds. Those found in the fine-grained limestones often are silicified. Though dismembered remains of crinoids are nearly always present in the beds of this formation, good heads are not generally plentiful. Here and there, however, notably in Pulaski and Grayson counties, they occur in rich colonies.

The following composite list of the Glen Dean fossils is made up of four collections taken from as many widely separated places in Kentucky, namely: (1) in the vicinity of Smithland, Livingston County; (2) Belleville Spring, 7 miles north of Princeton, Caldwell County; (3) near Grayson Springs, Grayson County; and, (4) from material taken out of the railroad tunnel at Sloans Valley, Pulaski County. The contents of the several collections are distinguished in the columns to the right of the list under corresponding numbers. A few species are credited to the Smithland column which were not found there but in the adjoining county of Crittenden. In similar manner the Grayson County occurrences have been increased by the addition of five or six species found in Breckinridge County. The fifth column shows the species so far identified in western Illinois. Names of species regarded as having a high practical value as guide fossils of the formation are prefixed by an asterisk. Those so marked are often found in the Glen Dean limestone, and, so far as known, they are found only in that limestone. Others, notably *Prismo-*

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pora serrulata and *Archimedes laxus*, might have been added to these starred species were it not that they are found also, though rarely, in the shaly beds of the Gasper limestone. However, in Kentucky the two mentioned species are so much more abundant in the Glen Dean than in the Gasper that their presence in a Kentucky collection may be accepted as reasonably conclusive evidence of its age. Of course ordinary caution would suggest procuring some corroborating testimony, either fossil or stratigraphic.

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Composite List of Fossils Found in the Glen Dean Formation in Livingston, Caldwell, Grayson and Pulaski Counties.

	I	II	III	IV	V
1. Zaphrentis spinulifera	X		X	X	
2. Pentremites calycinus?			X		
3.* Pentremites elegans	X		X	X	X
4. Pentremites cervinus	X		X		X
5.* Pentremites robustus			X	X	
6.* Pentremites robustus hemisphericus			X	X	X
7. Pentremites obesus modestus n. var.†	X		X	X	
8. Pentremites n. sp. aff. Pentremites obesus				X	
9. Pentremites hambachi n. sp.			X		X
10.* Pentremites canalis n. sp.			X	X	X
11. Pentremites angularis	X		X		
12.* Pentremites fohsi	X			X	X
13. Pentremites marionensis	X				
14. Pentremites cherokeeus			X	X	X
15. Pentremites spicatus n. sp.			X		?X
16.* Pentremites subplanus n. sp.			X	X	X
17. Pentremites simulans n. sp.				X	X
18. Pentremites tulipæformis				X	X
19.* Pentremites brevis n. sp.			X	X	X
20.* Pentremites lyoni n. sp.	X		X	X	X
21. Pentremites pyramidatus	X	X		X	X
22. Pentremites pyramidatus var. planulatus n. var.			X	X	X
23. Pentremites clavatus			X		X
24. Acrocrinus shumardi			X	X	
25. Poteriocrinus? anomalus				X	
26. Poteriocrinus? pulaskiensis				X	
27. Poteriocrinus? vagulus				X	
28. Pachylocrinus spinifer				X	
29. Scytalocrinus wetherbyi				X	
30. Scytalocrinus wachsmuthi				X	
31. Decadocrinus milleri				X	
32. Zeacrinus magnoliæformis			X		X
33. Zeacrinus florealis			X		
34. Zeacrinus ovalis			X		
35. Zeacrinus cylindricus				X	
36. Zeacrinus pulaskiensis				X	
37. Zeacrinus durabilis				X	

†Unfortunately, the illustrations of only three of the Birdsville species of Pentremites could be completed for this work. The others must await some future opportunity.

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Composite List of Fossils Found in the Glen Dean Formation in Livingston, Caldwell, Grayson and Pulaski Counties.—Continued.

	I	II	III	IV	V
38. Zeacrinus peculiaris				X	
39. Zeacrinus kentuckyensis				X	
40. Hydreionocrinus depressus Wetherby (?Hall)				X	
41. Hydreionocrinus wetherbyi				X	
42. Eupachycrinus maniformis			X		X
43. Eupachycrinus boydi			X		X
44. Eupachycrinus spartarius				X	
45. Eupachycrinus gracilis				X	
46. Agassizocrinus conicus	X	X	X	X	X
47. Agassizocrinus gibbosus			X		X
48. Pterotocrinus depressus	X	X	X	X	X
49. Pterotocrinus pyramidalis			X		
50.* Pterotocrinus acutus				X	
51. Pterotocrinus spatulatus	X			X	
52.* Pterotocrinus bifurcatus			X	X	X
53. Pterotocrinus wetherbyi				X	
54. Taxocrinus wetherbyi				X	
55. Onychocrinus pulaskiensis				X	
56. Agelacrinus pulaskiensis				X	X
57. Vinella sp.			X	X	
58. Hederella sp.	X		X	X	
59. Fistulipora excellens	X	X	X	X	X
60. Fistulipora n. sp.	X				
61.* Eridopora macrostoma	X			X	X
62. Eridopora aff. macrostoma (has smaller zoocia)	X			X	
63. Eridopora punctipora			X	X	X
64.* Chilotrypa hispida			X	X	
65.* Meekopora clausa	X		X	X	X
66. Meekopora approximata	X	X		X	X
67. Meekopora n. sp.			X	X	
68. Stenopora tuberculata	X	X	X	X	X
69.* Stenopora ramosa			X	X	X
70. Stenopora rudis				X	
71.* Anisotrypa symmetrica	X		X	X	X
72. Anisotrypa solida	X	X		X	X
73. Anisotrypa n. sp.		X			
74. Lioclema araneum	X	X		X	X
75. Batostomella nitidula				X	X

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Composite List of Fossils Found in the Glen Dean Formation in Livingston, Caldwell, Grayson and Pulaski Counties.—Continued.

		I	II	III	IV	V
76.	Batostomella spinulosa	X			X	X
77.	Batostomella sp.?			X		X
78.	Batostomella abrupta	X			X	
79.	Rhombopora armata			X	X	
80.	Rhombopora persimilis	X		X	X	X
81.	Rhombopora minor	X		X	X	X
82.	Rhombopora tabulata	X		X	X	X
83.	Rhombopora tenuirama	X		X	X	X
84.	Streblotrypa nicklesi		X	X	X	X
85.	Streblotrypa distincta		X			X
86.	Streblotrypa subspinosa				X	X
87.	Prismopora serrulata	X		X	X	X
88.	Dichotrypa sp.?	X				
89.	Stictoporella? undulata			X		
90.	Fenestella serrulata	X		X	X	X
91.	Fenestella tenax	X		X	X	X
92.	Fenestella aff. multispinosa	X	X		X	X
93.	Fenestella cestriensis	X		X	X	X
94.	Fenestella aff. conradi	X	X			
95.	Fenestella flexuosa			X	X	
96.	Fenestella cf. compressa				X	
97.	Fenestella elevatipora	X				
98.	Archimedes communis	X		X	X	X
99.	Archimedes compactus				X	X
100.	Archimedes intermedius	X	X		X	X
101.	Archimedes cf. swallovanus	X		X		X
102.	Archimedes invaginatus		X	X		X
103.	Archimedes terebriformis	X		X	X	X
104.	Archimedes distans	X	X		X	X
105.	Archimedes meekanus	X		X	X	X
106.	Archimedes laxus	X	X	X		X
107.	Archimedes proutanus				X	X
108.	Lyropora ranosculum			X	X	X
109.	Lyropora subquadrans				X	X
110.	Lyropora quincuncialis	X		X		X
111.	Lyropora divergens				X	X
112.	Lyropora ovalis			X		
113.	Polypora cestriensis		X	X	X	X
114.	Polypora tuberculata		?	X		X
115.	Polypora corticosa	X		X		X

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Composite List of Fossils Found in the Glen Dean Formation in Livingston, Caldwell, Grayson and Pulaski Counties.—Continued.

		I	II	III	IV	V
116.	Polypora spinulifera			X	X	X
117.	Polypora approximata	X		X	X	X
118.	Thamniscus furcillatus			X	X	X
119.	Thamniscus ramulosa			X	X	X
120.	Septopora cestriensis?		X		X	X
121.	Septopora subquadrans	X			X	X
122.	Septopora decipiens			X	X	
123.	Septopora biserialis nervata			X	X	
124.	Septopora robusta intermedia			X	X	
125.	Sphragiopora parasitica	X			X	X
126.	Crania chesterensis	X			X	X
127.	Productus scabriculus?	X	X		X	
128.	Productus pileiformis	X	X	X	X	X
129.	Diaphragmus elegans var.	X		X	X	
130.	Spirifer increbescens	X	X	X	X	X
131.	Spirifer increbescens var. (very elongate)		X			
132.	Spirifer aff. breckinridgensis	X				
133.	Spiriferina spinosa	X	X			X
134.	Spiriferina aff. spinosa (hinge very short)	X				
135.	Spiriferina transversa	X	X			
136.	Reticularia setigera				X	X
137.	Composita subquadrata	X				
138.	Cliothyridina sublamellosa	X			X	
139.	Eumetria vera or verneuliana?	X			X	
140.	Camarophoria explanata	X				
141.	Dielasma shumardanum	X	X			
142.	Dielasma cf. formosa	X			X	
143.	Girtyella cf. brevilobata	X			X	
144.	Spirorbis sp.	X			X	
145.	Aviculopecten sp.	X				
146.	Allerisma sp.		X			
147.	Bellerophon sp.	X				
148.	Euomphalus sp. aff. E. planodorsatus	X				
149.	Platyceras sp.	X			X	
150.	Pleurotomaria n. sp. (related to P. chesterensis)	X				
151.	Orthoceras sp. (small simple type)	X			X	
152.	Primitia granimarginata†			X		
153.	Ulrichia emarginata			X		

†Ostracoda, probably of species here listed, occur at other Glen Dean limestone localities in Kentucky but only those from Grayson County have been studied.

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Composite List of Fossils Found in the Glen Dean Formation in Livingston, Caldwell, Grayson and Pulaski Counties.—Continued.

	I	II	III	IV	V
154. Beyrichiella confluens	.		X		
155. Hollina radiata var. cestriensis			X		
156. Beyrichia? simulatrix			X		
157. Moorea granosa			X		
158. Kirkbya oblonga var.			X		X
159. Kirkbya tricollina			X		
160. Kirkbya venosa			X		
161. Bairdia cestriensis			X		
162. Phillipsia sp.				X	

As shown by the above list, a large part of the Glen Dean fauna of Kentucky is found also in the Randolph County area of Illinois. At that it is to be observed that only the Pentremites and the Bryozoa of the two areas have been compared with any pretence to thoroughness. If similarly complete investigation of the Illinois crinoids, brachiopods, and other fossils, were to be made, it is scarcely to be doubted that these also would exhibit a correspondingly large proportion of species common to Kentucky and western Illinois. Taking the results of the comparisons so far as accomplished, we find that most of the Glen Dean fossils marked as found in the Randolph County area in Illinois occur there in the 40 feet or so of shaly limestone ("Plum Creek beds") that has been included by Weller—somewhat unnaturally I think—in the top of the Okaw limestone. More important is the fact that the species which are regarded as strictly characteristic of the Glen Dean limestone in Kentucky are, so far as known, similarly confined in Illinois to these upper Okaw beds. According to the faunal evidence, therefore, the latter are confidently assigned to the age of the Glen Dean.

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FOSSILS OF THE MENARD LIMESTONE.

The Menard limestone always contains some fossils. In fact a complete list of its fauna would most probably comprise 100 species. Locally, too, it contains beds literally crowded with fairly good specimens. Taken as a whole, however, it is far less fossiliferous than the Glen Dean limestone, and less also than either the Gasper or the Clore, though the disparity is not so great in these cases.

In its composition the Menard fauna reminds of the fauna found in the limestones of the Golconda and Gasper. Like the Golconda fauna, that of the Menard includes relatively few Bryozoa, being made up mainly of shells of brachiopods, pelecypods, and gastropods. Only a few of the rarer brachiopods are strictly characteristic of the formation, the most of them being held in common with underlying formations. Among the restricted species is a large undescribed Glossina which unfortunately is but rarely found. Of the more widely ranging species *Camarophoria explanata* occurs, at least in western Kentucky, more abundantly in the Menard than elsewhere. *Spirifer increbescens* also is very common, but the variety that represents the species here differs appreciably from its predecessors in being thicker, more gibbous, and relatively shorter at the hinge-line. With such qualified exceptions the brachiopods must be set down as of questionable value in recognizing the formation.

The pelecypods as a rule also are too much like preceding and succeeding occurrences to be of much practical help in fixing the age of outcrops as Menard limestone. The only notable exception is a large species of *Sulcatopinna*—somewhat doubtfully identified with *Sulcatopinna missouriensis*—which is seldom wholly wanting in large exposures of this limestone. Besides, there is reason to believe that close study of the four or more species of *Aviculopecten* will disclose characters by which they may be definitely distinguished from the representatives of the same genus in the underlying Golconda, Gasper, and Ste. Genevieve limestones and the overlying Clore formation. Preliminary comparisons of specimens from these different beds indicate

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that those in the Menard are not exactly like any others. The *Monotis?*, however, seems indistinguishable from the Golconda species; and the same is to be said of the *Pteronites, Solenomya,* and the two species each of *Schizodus* and *Allerisma.* The *Modiola,* though much like the *Modiola illinoiensis* of the Gasper and Ste. Genevieve, yet seems distinguishable and may prove a valuable guide. Finally, the *Sanguinolites* appears to be distinct from all preceding shells. Being also of a large size, it promises to make a good index fossil. So far as known it is confined to the Menard.

The few gastropods also seem likely to prove of value as index fossils. The *Bucanopsis* is a large species with markings as in *Bucanopsis textilis.* Besides, it is common and generally distributed, though good specimens are relatively rare. The *Euomphalus* also is a well-marked and widely distributed species. Its relations are with Pennsylvanian species rather than earlier Chester forms.

The following list is made up from material gathered at a single locality in the eastern part of Caldwell County. Here, at a point about 1 mile west of Claxton station, the limestone forms a rocky hillside and glade several acres in extent in which every foot of 50 to 60 feet of beds is accessible. Altogether it is the best exposure of weathered Menard limestone known to me in western Kentucky. The fossils occur mainly in the lower half. The upper half consists largely of yellowish or grayish indurated claystone, more or less calcareous and of concretionary structure. Fossils occur in some of these upper beds but they are far from abundant and usually hardly worth the effort of collecting them.

Other good exposures of Menard limestone occur east of Marion, at Tribune, in Crittenden County, and to the northeast of Marion, near Repton. At these places the limestone is, on the whole, firmer and purer and less richly fossiliferous than in the vicinity of Claxton. The fauna, too, is somewhat different, the Bryozoa and *Pretremites* being proportionately more abundant.

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Fossils from the Menard Limestone, 1 to 2 Miles West of Claxton, Caldwell County, Kentucky.

1. Pentremites cherokeeus var.
2. Agassizocrinus conicus.?
3. Meekopora cf. approximata.
4. Batostomella nitidula.
5. Leioclema n. sp.
6. Fenestella, 2 or 3 undet. sp.
7. Polypora sp. undet.
8. Septopora sp. undet.
9. Lingula sp.
10. *Glossina aff. scotica (1 inch or more in length).
11. Crania chesterensis?
12. Orthothetes kaskaskiensis.
13. Productus pileiformis.
14. Productus cf. scabriculus.
15. Diaphragmus elegans.
16. *Camarophoria explanata.
17. Dielasma cf. formosa.
18. Girtyella sp.
19. Eumetria vera.
20. Eumetria cf. verneuliana.
21. Composita subquadrata.
22. Cliothyridina sublamellosa.
23. *Spirifer increbescens.
24. Spirifer cf. breckenridgensis.
25. Reticularia setigera.
26. *Sulcatopinna missouriensis.
27. Pteronites sp. (same in the Golconda formation).
28. *Myalina angulata.
29. *Modiola n. sp. (aff. Modiola illinoiensis).
30. *Aviculopecten, 4 undet. sp.
31. Monotis sp. (same in Golconda formation).
32. Solenomya cf. n. sp. in Golconda formation.
33. Nucula sp.
34. Leda sp.
35. Conocardium sp. (small, related to Ste. Genevieve species).
36. Schizodus sp. (same in Golconda formation).
37. Schizodus (aff. compressus Worthen).
38. *Sanguinolites sp.
39. Allerisma?, 2 sp. (cf. Golconda species).
40. *Bucanopsis n. sp. (aff. Bucanopsis textilis).
41. *Euomphalus aff. subquadratus.
42. Conularia chesterensis.
43. *Phillipsia n. sp.

Species marked with an asterisk are regarded as the most useful in identifying the formation.

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FOSSILS OF THE CLORE FORMATION.

In western Kentucky the Clore formation consists mainly of interbedded limestone and shale, with an occasional layer of sandy limestone or sandstone. Most of these rocks contain fossils, the thin-bedded limestones and their calcareous shale partings often being filled with them. Locally the sandy beds also are crowded with fossils, but the remains in these consist almost entirely of pelecypods. In the other beds, on the contrary, the Bryozoa and Brachiopoda predominate almost to the exclusion of the molluscan remains, the only conspicuous exception being a large, specifically undetermined Bellerophon.

Fossils were collected by me from this uppermost formation of the Chester series at many places during the early years of my work in western Kentucky. At only one of these places, however, was any determined effort made to procure an approximately full representation of the fauna. This was at Claxton Station in the eastern part of Caldwell County, where the lower and middle parts of the formation were then well exposed in cuttings along the railroad. The following list is made up entirely from material gathered at this place. It gives not only a fair idea of the fauna of the formation as a whole, but an even better conception of its development in a limited area during the early and middle parts of this geological age. Similarly careful search of other outcrops of the formation, particularly those in Livingston County, doubtless would add considerably to the Clore fauna in western Kentucky. Judging from data in hand the total number of species most probably would exceed 75.

Comparison with the Clore formation at its typical locality in Randolph County, Ill., shows that in lithologic and faunal characters the Kentucky beds from which the following fauna was collected are practically identical with their Illinois representatives. Furthermore, in both areas the formation is unconformably overlain by Pennsylvanian sandstones and underlain by a clearly corresponding sequence of Palestine sandstone, Menard limestone, Tar Spring sandstone, and shaly Glen Dean

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limestone. There is, therefore, no reasonable ground for doubt regarding the propriety of using the same term—Clore formation—for the closing stage of the Chester series in western Kentucky as in Illinois.

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Fossils from the Clore Formation at Claxton, Caldwell County, Kentucky.

1. Echinoid of undet. genus.
2. Chaetetes n. sp.
3. Pentremites serratus.
4. Pentremites, large, n. sp.
5. Vinella n. sp.
6. Ascodictyon n. sp.
7. Fistulipora aff. excellens.
8. Fistulipora, sp. 2.
9. Stenopora n. sp. aff. Stenopora tuberculata.
10. Anisotrypa symmetrica.
11. Lioclema araneum.
12. Lioclema n. sp. (tuberculated, same in Menard limestone).
13. Batostomella nitidula.
14. Sphragiopora parasitica.
15. Fenestella, 3 or 4 species, all closely allied to or the same as Glen Dean species.
16. Polypora approximata.
17. Polypora n. sp. (allied to Polypora approximata and Polypora tuberculata).
18. Archimedes meekanus.
19. Archimedes intermedius.
20. Archimedes distans.
21. Septopora subquadrans.
22. Crania chesterensis.?
23. Orthothetes kaskaskiensis.?
24. Productus cf. scabriculus.
25. Productus cf. pileiformis.
26. Diaphragmus cf. elegans var. 1.
27. Diaphragmus cf. elegans var. 2.
28. Camarophoria explanata.
29. Spirifer increbescens.
30. Spirifer cf. breckinridgensis.
31. Reticularia setigera.
32. Spiriferina spinosa.
33. Spiriferina transversa.
34. Eumetria vera.
35. Composita subquadrata.
36. Sulcatopinna cf. missouriensis.
37. Sulcatopinna sp. undet. (small, 1 to 2½ inches long).
38. Myalina sp. undet.

39-42. Aviculopecten, 4 species, all apparently different from those in the Menard and Golconda formations.

43. Bellerophon sp.
44. Primitia caldwellensis.
45. Primitia subaequata.
45. Hollina radiata.
47. Cytherella ovatiformis.
48. Large fish spine.

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LEGENDS FOR PLATES G-1 AND G-2.*

Plate G-1. Bluff along St. Marys road, 2 miles south of Ste. Genevieve, Mo., showing overlapping base of Ste. Genevieve limestone on slightly eroded top of St. Louis limestone. Height of bluff about 20 feet.

Plate G-2. Nearer view of part of the face of a small quarry in the same bluff, 100 yards or so to the north, showing the same unconformable contact with more distinct evidence of erosion. The top of the St. Louis limestone here is crevassed with old joint planes subsequently enlarged by subaerial decomposition and finally filled with surface sweepings, including rounded igneous pebbles, prior to the beginning of normal deposition of Ste. Genevieve limestone.

*See Page 99.

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LEGENDS FOR PLATES H-1 AND H-2.*

Plate H-1. Part of cutting in face of bluff along an unfinished railroad, 5.5 miles east of Jasper, Tenn., and 1 mile north of Oats Island in Tennessee River. The lower part of the photograph shows the top of the Spergen limestone with evidence of gentle erosion of its surface prior to deposition of the superposed St. Louis limestone. This began with a fine-grained, laminated, argillaceous limestone, 0-24 inches thick, evidently representing the sorted product of washed surface debris. This was followed by normal St. Louis limestone containing an abundance of chert in nodules and uneven plates. Following the close of the St. Louis stage, emergence again prevailed with erosion vigorous enough to remove most of the St. Louis limestone. In places, as shown in the bluff, erosion cut entirely through the St. Louis, the succeeding Ste. Genevieve limestone being then in contact with the underlying Spergen limestone. In the left half of the photograph may be seen a joint plane—enlarged and filled with basal Ste. Genevieve conglomerate—recalling a similar phenomenon in the bluff on Mississippi River south of Ste. Genevieve, Mo. The maximum thickness of the remnant of St. Louis limestone in this picture is about 6.5 feet.

Plate H-2. Sketch of the bluff east of Jasper, Tenn., including parts adjacent to the east and west of that shown in the above photograph. The two remnants of St. Louis limestone are particularly noteworthy. The beds shown in the sketch are as follows: A, top beds of the Spergen oolite which passes downward into cherty, impure limestone of Warsaw age, the two together approximately 185 feet thick. At AA is a bed of intraformational conglomerate, 0-12 inches thick, consisting of rounded limestone pebbles up to 3 inches in diameter in a shaly matrix. To the left this pinches out in the midst of a massive ledge of oolite and subcrystalline limestone. (Probably comparable in origin and significance to the conglomerate locally found within or at the base of the "upper Ohara" in western Kentucky.) B, intermittent, laminated, argillaceous limestone, 0-24 inches thick, representing the initial deposit at the overlapping base of the St. Louis limestone. C, very cherty remnants of ordinary St. Louis limestone. In the left half of sketch it rests directly on the Spergen oolite. The contact between them, as also between A and B in the right half of sketch, exhibits evidence of a stratigraphic break and slight subaerial erosion. D, oolitic and subcrystalline gray limestone, 0-7 feet thick, constituting the varying basal layer of the overlapping Ste. Genevieve limestone. The contact between it and the underlying bed—in places A, in others either B or C—obviously marks a profound stratigraphic and erosional break. E, a variable bed of shaly, easily weathering limestone, absent in the west half of the bluff, suggesting the nearby existence at its date of unsubmerged land areas. F, more or less oolitic limestone of the kind usually found in the Fredonia oolite, containing *Michelinia princetonensis*, *Platycrinus huntsvillae*, *pentremites princetonensis*, and other fossils commonly found in the Ste. Genevieve limestone.

*See pages 101 and 102.

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DESCRIPTION OF PLATE 1.

Corals of the Ste. Genevieve Limestone.

Figs. 1–13. *Zaphrentis? radicosa* Ulrich, n. sp.

1–6. Six specimens showing variation in relative expansion of cup and the characteristic rootlike processes on the lower and middle parts. Evidently these processes served to join and support neighboring corallites in a composite corallum.

7. Fractured corallite showing the convex tabulae.

8–11, 13. Calycular ends of specimens showing flatness of middle area of bottom of cup and the imperfect development of the fossula. These characteristic features of the species suggest *Amplexus* and *Bordenia*. Figure 8 shows the cup of original of figure 1, figure 9 of figure 3, figure 10 of figure 6, figure 11 of figure 5, figure 13 of figure 4.

12. Broken calyx of the largest specimen found. A young specimen is attached to the upper side.

All of these specimens were collected from an exposure of the upper third of the Fredonia oolite member of the formation near Wilson Station in Caldwell County, Ky., along the road from Princeton to Fredonia. They are now in the U. S. National Museum under the number 64780. Comparisons with other species seem unnecessary because none at all likely to be confused with it is known in rocks of similar age.

Figs. 14–21. *Zaphrentis pellaensis* Worthen.

14, 15. Views of the side and calyx of a nearly complete silicified specimen. Upper third of Fredonia member, 5 miles northwest of Princeton, Ky. U. S. National Museum No. 64784.

16, 17. Calycular views of two other specimens with the marginal parts of the cup broken away. Upper part of Fredonia member, 1 to 2 miles northwest of Princeton, Ky. U. S. National Museum No. 64785.

18, 19. Side and calycular views of a specimen showing depth of cup. Upper half of Fredonia member in Livingston County, Ky., near Salem. U. S. National Museum No. 64801.

20. An imperfect silicified specimen from same place and formation as 16 and 17. U. S. National Museum No. 64785a.

21. Side view of a specimen preserving characters of the surface. Zone 3 of the Ohara member, 4 miles west of Marion, Ky. U. S. National Museum No. 64802.

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Figs. 22-24. *Menophyllum excavatum* Ulrich, n. sp.

22. Calycular view of the holotype. In side view the corallum of this species is about as in figure 26. The marginal part of the cup is broken away but the characteristically broad, deep, steeply sloping, pear-shaped median cavity and the three fossulae are well shown. Upper third of the Fredonia member, Princeton, Ky. U. S. National Museum No. 64811.

23. A smaller example from same bed and locality. U. S. National Museum No. 64811a.

24. Another specimen broken so as to show part of the preceding tabulum. From the same bed and locality. U. S. National Museum No. 64811b.

Fig. 25. *Menophyllum haimeanum* Ulrich, n. sp.

The imperfect calyx of the holotype of this species. The general form of the corallum is practically the same as in the preceding and succeeding species but it is easily recognized by the extraordinary development of the fossulae, they being wider and deeper than in the other species. Upper third of the Fredonia member, Princeton, Ky. U. S. National Museum No. 64812.

Figs. 26–28. *Menophyllum princetonensis* Ulrich, n. sp.

26, 27. Side and calycular views of a nearly complete specimen.

28. The cup of another specimen. Upper third of the Fredonia member, near Princeton, Ky. U. S. National Museum Nos. 64813, 64813a.

The species is distinguished from its congeners by the relative narrowness of its fossulae. Other differences doubtless will be observed in comparing the figures of its cup (27 and 28) with similar illustrations of *M. excavatum* and *M. haimeanum* on this plate.

Figs. 29, 30. *Palaeacis* aff. *cuneiformis* Milne-Edwards.

29. Side view of a specimen with three cups. Fredonia member of the Ste. Genevieve limestone, 4½ miles west of Marion, Ky. U. S. National Museum No. 64815.

30. View of the base of another specimen with only two cups. Upper cherty bed of the Fredonia member. U. S. National Museum No. 64816.

Though these Fredonia specimens are not exactly like young coralla of the Spergen limestone fossil, *P. cuneiformis*, the material in hand seems insufficient to warrant giving them a distinct name.

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DESCRIPTION OF PLATE 2.

Lower (Monte Sana) Chester Pentremites and Batocrinidae.

Figs. 1–7. *Pentremites pulchellus* Ulrich, n. sp. (*Pentremites floralis* part Ulrich, 1905, U. S. Geol. Survey Prof. Paper 36, pl. 6, figs. 18b, d.)

1. A mutation of the typical form of this species in which the ambulacral areas are slightly wider than they should be. Upper part of the Fredonia oolite, 1 mile east of Princeton, Ky. U. S. National Museum No. 64789.
2. The holotype of the species. From upper part of the Fredonia oolite at Bakers Station, 2 miles southeast of Fredonia, Ky. U. S. National Museum No. 64788.
3. A nearly typical specimen differing only in its slightly more slender form. From the same bed and place as the preceding. U. S. National Museum No. 64788a.
4. A variety distinguished by its relatively slender form and somewhat fuller base. In all respects except the last this is intermediate in character between figures 1 and 5. From zone 3 of the Ohara member, near Carrsville, Ky. U. S. National Museum No. 64790.
5. A large specimen of the slender variety. From the main *Platycrinus huntsvillae* bed of the Ste. Genevieve part of the Monte Sana limestone, near Huntsville, Ala. Springer collection in U. S. National Museum.
6. Small but fairly typical specimen. From the upper Ohara near Marion, Ky. U. S. National Museum No. 64787. This specimen exhibits a greater degree of resemblance to *P. conoideus*, the Spergen ancestor of this species, than has been observed in any other of the Ste. Genevieve collections studied.
7. Small specimen of an obese mutation reminding of the young of *P. pinguis*. Upper part of the Fredonia oolite, Princeton, Ky. U. S. National Museum No. 64786.

In perhaps all essential respects *Pentremites pulchellus* is genetically intermediate between the adolescent stages of *P. conoideus* (which Hall distinguished under the name *P. koninckianus*), a well known Meramec species, and *P. symmetricus*, a characteristic and common fossil in the Renault and Paint Creek formations in southwestern Illinois. In the Ste. Genevieve stage of the evolution of this group of *Pentremites* the characters which marked the adolescent form of *P. conoideus* persisted through the mature stages of the individual so that old specimens of *P. pulchellus*, as it is proposed to call the Ste. Genevieve form, are not likely to be confused with mature examples of *P.*

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conoidcus. Structural differences, too, were sustained. Thus, the ambulacral arms, which are very narrow on the older form, are considerably wider in *P. pulchellus* though not so wide as they became in the Renault derivatives. Besides, the interambulacral areas had become less concave. But a more conspicuous and perhaps more important difference is in the basal part of the calyx, this being drawn out to form a short peduncle in *P. pulchellus*, whereas in *P. conoidcus* the attachment of the column is at a plane lying very little beneath the lower edge of the ring of basal plates. Finally, the diameter of the head of the column is constantly somewhat larger in *P. conoideus*.

Compared with the succeeding *P. symmetricus* it is found that most of the modifications mentioned have proceeded a step farther. The base in the latter is relatively much longer, the ambulacral areas still wider, and the interambulacral spaces have become almost flat. The exception to this progressive development is that the pediculation of the base remained proportionately about the same in mature examples of *P. pulchellus* and *P. symmetricus*, whereas in young specimens of the latter a peduncle is scarcely suggested. After all, however, the most striking difference between the two species is in their respective dimensions, fully grown individuals of *P. pulchellus* attaining but half or even only a third of the length and width of average to large specimens of *P. symmetricus*.

Figs. 8–14. *Pentremites princetonensis* Ulrich, n. sp. (*Pentremites floralis* part Ulrich, 1905, U. S. Geol. Survey Prof. Paper 36, pl. 6, figs. 18a, c).

8, 9. Two specimens of the typical form, both slightly smaller than average size. Main cherty zone of the Fredonia oolite, at Princeton, Ky. U. S. National Museum Nos. 64791, 64791a.

This is the most common species of the genus in the Ste. Genevieve limestone. It is distinguished from the preceding (*P. pulchellus*) by its broader form, relatively larger and fuller base, and less concave interambulacral spaces. It ranges from the middle part of the Fredonia to zone 3 of the Ohara member. A variety, distinguishable only when the specimens preserve the minute characters of the ambulacral areas, is found in both the Renault and the Paint Creek formations in Illinois. Though common in these formations this variety is rare in the corresponding divisions of the Gasper oolite in Kentucky.

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10, 11. Two medium-sized, fairly typical specimens. From zone 3 of the Ohara member of the Ste. Genevieve limestone, 3 miles northwest of Marion, Ky. U. S. National Museum Nos. 64790, 64790a.

Younger specimens from the same locality have (like figs. 8 and 9) relatively more obconical bases; and in yet older examples the common tendency among *Pentremites* to reduce the height of the base is carried on to the extreme illustrated in figures 12 and 13.

12. The largest and most obese specimen so far observed, showing flattening of base with age and consequent resemblance to *P. pinguis*. Upper Ohara, 2 miles east of Carrsville, Ky. U. S. National Museum No. 64793.

13. Another large but narrower example, somewhat crushed. From the Fredonia oolite at View, Ky. U. S. National Museum No. 64792.

Figs. 14, 15. *Pentremites tuscumbiae* Ulrich, n. sp.

14. Anterior view of the holotype. Ste. Genevieve limestone part of the Monte Sana limestone, near Tuscumbia, Ala. U. S. National Museum No. 64795.

15. Slightly crushed specimen. From the upper Ohara, 2 miles east of Carrsville, Ky. U. S. National Museum No. 64793.

This species is closely allied to *P. princetonensis*, but mature specimens (compare figs. 12 and 13 with 14 and 15) are easily distinguished by the higher and more obconical base, the more definite development of the ridges running from the extremites of the ambulacral areas toward the columnar facet, and the greater concavity of the interambulacral spaces in *P. tuscumbiae*. It is related also to *P. symmetricus*. In fact it seems the most probable link betwen that species and *P. princetonensis*.

Figs. 16, 17. *Pentremites pinguis* Ulrich, n. sp. (*Pentremites floralis* part Ulrich, 1905, U. S. Geol. Survey Prof. Paper 36, pl. 6, figs. 18e, f).

16. Another view of a rather small specimen. Fredonia oolite, at View, Ky. U. S. National Museum No. 64797. The two specimens illustrated in 1905 are even smaller.

17. Postero-lateral view of the holotype of this species. Upper Ohara, 2 miles east of Carrsville, Ky. U. S. National Museum No. 64796.

The nearly flat base and broadly rounded crown distinguish this species from *P. princetonensis*. In both of these features it resembles *P. cavus* Ulrich, a lower or middle Meramec species, but the much shallower ex-

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cavation of the interambulacral areas and the wider ambulacra in *P. pinguis* at once establish its distinctness. Much closer, though yet distinguishable relatives are found in the Renault and Paint Creek formations in Illinois.

Figs. 18, 19. *Pentremites buttsi* Ulrich, n. sp.

18. Lateral view of the holotype. Toward the top of the right side of the figure is a diagram showing the contour of one of the ambulacral areas in transverse section. Zone 4 of the Ohara member, Downeys Bluff, at Rosiclare, Ill. U. S. National Museum No. 64808.

19. A young specimen. Found in zone 3 of the Ohara, near Shettlerville, Hardin County, Ill. U. S. National Museum No. 64809.

This is the oldest of the known appearances of the group of *P. pyriformis*. Its relatively short base and flat ambulacral areas distinguish it from most of the Gasper species of its group. Critically compared with these it proves to be most like *P. patei* Ulrich, n. sp., but is clearly shown to be distinct by its coarser (hence relatively fewer) ambulacral ossicles, more slender form, and proportionately shorter and more pedunculate base. Another but less close relative is *P. abruptus* Ulrich, n. sp. In this Gasper species, however, the width of the calyx is at all times greater, and the peduncle more distinctly formed than in *P. buttsi*. Finally, *P. buttsi* has at times been confused with *P. symmetricus* Hall, a common fossil in the Renault and Paint Creek formations in southwestern Illinois. In fact these two forms are quite distinct, Hall's species being derived out of the stock of *P. conoideus* through *P. pulchellus* and possibly *P. tuscumbiae*. The present species, on the contrary, belongs to the line of *P. pyriformis* whose root is yet unknown.

Fig. 20. *Pentremites prematurus* Ulrich, n. sp.

Posterior side of the small, possibly young, holotype of this species. Above is a diagrammatic cross section of one of the ambulacral areas. Zone 3 of the Ohara member, near Shettlerville, Ill. U. S. National Museum No. 64810.

The general form of this rare praenuntial species is much like that of the young of *P. girtyi* and *P. canalis*, new species—the first from the Gasper oolite, the second from the Glen Dean limestone. However, it can not be identified with either, the base being relatively shorter and the ambulacral areas more deeply excavated than in

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P. girtyi, whereas the lower extremity of the base is more pedunculate than is the corresponding part in the young of *P. canalis*.

Figs. 21–23. *Dizygocrinus superstes* Ulrich, n. sp. and variety.

21, 22. Postero-lateral and basal views of the holotype of this species. Upper part of the Fredonia oolite, 2 miles east of Princeton, Ky. U. S. National Museum No. 42245.

This species is related to *D. unionensis* (Worthen), another Ste. Genevieve limestone fossil, but has fewer interbrachials and a different ornamentation of the plates of the calyx. It should be noted that the interbrachials are four in number on the azygous side and three between the other rays, thus suggesting actinocrinoid rather than batocrinoid affinities.

23. Lateral view of a small specimen provisionally referred to this species as a variety. It is relatively somewhat narrower than the type and differs further in having but two interbrachials where that has three. These plates are the same in number as in figure 28 in which, however, the basal cone of the calyx is relatively lower. Zone 2 of the Ohara at Cedar Hill, 3 miles east of Princeton, Ky. U. S. National Museum No. 42243.

Precisely similar specimens occur also in the Fredonia oolite near Princeton.

Figs. 24–26. *Dizygocrinus persculptus* Ulrich, n. sp.

24. View of the base of the holotype, the plates at the top and bottom covered with stone, since removed. Upper part of Ohara limestone, 2½ miles north of Smithland, Ky. U. S. National Museum No. 64781.

25. Lateral view of same. The spines on the upper surface are very prominent and cylindrical rather than conical.

26. The left posterior and right anterior rays, X 2, showing two interbrachial plates between them. The azygous interbrachials (5) are shown in outline.

This species has not been recognized beneath the Ohara. However, it may well occur also in the Fredonia because its nearest relatives are two Spergen oolite species, *Dizygocrinus decoris* Miller and *Batocrinus icosidactylus* Casseday. It is distinguished from these by having fewer interbrachials.

Fig. 27. *Batocrinus* aff. *cuconus* M. and W.

Basal view of calyx showing seven interbrachial plates on the anal side and four or five between the other rays. Fredonia oolite, half a mile south of the Columbia mine, west of Marion, Ky. U. S. National Museum No. 42350.

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This species is closely allied to *B. euconus*, a Spergen oolite fossil, but is distinguished by its highly sculptured plates. A smaller but otherwise closely simulating specimen was collected out of zone 2 of the Ohara at Cedar Hill, near Princeton, Ky.

Fig. 28. *Dizygocrinus* cf. *persculptus*.

Basal view of a weathered calyx doubtfully referred to this species. The anal cluster of interbrachial plates consists of only four instead of five plates. Compare also the variety of *D. superstes* (fig. 23). Ohara member, 2½ miles north of Smithland, Ky. U. S. National Museum No. 64782.

Figs. 29–32. *Agassizocrinus* sp.? (Cf. *A. ovalis* Miller and Gurley).

Four specimens in different views of the ancylosed basal plates of a species resembling but evidently distinct from *A. conicus*. Though never very abundant, this fossil is widely distributed and characteristic of the upper part of the Gasper oolite. The corresponding part of the calyx in *A. conicus*, which seems confined to Birdsville formations, forms a higher cone, whereas this form commonly is approximately semiorbicular. The originals of figures 29, 30, and 32 are from Lambs Cut, 3 miles east of Scottsburg, Ky. Ulrich collection, U. S. National Museum Nos. 64807, a, b. That of figure 31 is from the Paint Creek formation on Barbeau Creek, in the northern part of Randolph County, Ill. Springer collection, U. S. National Museum.

Fig. 33. *Mesoblastus glaber* var. *sphaeroidalis* (M. and G.)

Lateral view of a rather small specimen of this variety, from the upper part of the Gasper oolite, at Lambs Cut, 3 miles east of Scottsburg, Ky. U. S. National Museum No. 64783. Miller and Gurley's type came from corresponding beds in Meade County, Ky. The same variety is found also in the Paint Creek formation, in the northern part of Randolph County, Ill., and in Jones County, east Tennessee.

Figs. 34–36. *Pentremites biconvexus* Ulrich, n. sp.

34, 35. A photograph and a drawing of the anterior side of the holotype. Gasper oolite, near Bowling Green, Ky. U. S. National Museum No. 64820.

36. Lateral view of a smaller and somewhat imperfect specimen from oolite in the upper division of the Gasper oolite, in Christian County, Ky., about 2 miles southeast of the Caldwell County line. U. S. National Museum No. 64821.

This fine species is related to and found associated

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with *P. godoni* and *P. planus* but is readily distinguished by its less flattened base, protuberant basal plates, and more or less distinctly biconvex ambulacral areas. The last feature is notable also in one of the varieties of *P. planus*.

Figs. 37–40. *Pentremites arctibrachiatus* Ulrich, n. sp.

37, 38, 40. Three specimens from the Gasper part of the Monte Sana limestone, near Huntsville, Ala., on which the species is founded. U. S. National Museum Nos. 64817, a, b.

The essential characteristics of the species lie in the relative narrowness and approximate transverse flatness of the ambulacral areas. Compared with otherwise similar species it is further distinguished by its slender pedunculate base. In the young of *P. buttsi* the form of the base is much the same, but the summit is less rounded and later grows proportionately taller; and its poral pieces are thicker and the ambulacra wider.

39. A specimen from the Renault formation 2 to 3 miles northwest of Floraville, Ill., referred to this species. Springer collection, U. S. National Museum.

Figs. 41, 42. *Pentremites arctibrachiatus* var. *huntsvillensis* Ulrich n. var.

Two specimens showing the peculiarities that seem to require their separation from the typical form of the species. It will be observed that their ambulacral areas are slightly channel-like in cross section and that they are wider above than they should be. The deltoid plates also are smaller. The variety resembles *P. girtyi* in its general aspect but on close comparison the poral pieces are found to be smaller and the interambulacral spaces distinctly concave instead of flat. Gasper part of the Monte Sana limestone, Huntsville, Ala. Springer collection, U. S. National Museum.

43. *Pentremites abruptus* Ulrich, variety of.

A rather young specimen of a well-marked variety of this species, figured here for comparison with *P. huntsvillensis*. Gasper division of Monte Sana limestone, near Huntsville, Ala. U. S. National Museum No. 64822.

44. *Pentremites pediculatus* Ulrich, n. sp.

Anterior view of the holotype. Gasper oolite near Bowling Green, Ky. U. S. National Museum No. 64826.

This rare species has its closest relative in *P. arctibrachiatus* and *P. godoni* but is distinguished from both by the large size of its deltoid plates and, especially from the latter, by its much more strongly pediculate base. The ambulacral areas are biconvex and slightly depressed in the middle; the interambulacral spaces are distinctly though not deeply concave.

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DESCRIPTION OF PLATE 3.

Chester Productidae in the Fredonia Oolite.

Figs. 1–3 *Productus arkansanus* Girty.

1. Pedicle valve showing the general form and the nodular plications which characterize this well-marked species. Found in association with *Productus inflatus*, *Diaphragmus elegans*, and *Echinoconchus genevievensis* in the main cherty zone of the Fredonia oolite at Princeton, Ky. U. S. National Museum No. 64831.

2, 3. Pedicle views of two specimens of this species found in the Menard limestone near Claxton, Caldwell County, Ky. The species is one of the most characteristic fossils of the Chester series in western Kentucky. It ranges with exceedingly little modification from the lowest to the highest division of the series. Indeed, comparison of its several occurrences has so far failed to indicate a single character by which they may be distinguished. U. S. National Museum Nos. 64832, 64832a.

Figs. 4–13. *Productus inflatus* and varieties.

4–6. Pedicle views of three specimens referred to this species. From the main cherty zone of the Fredonia oolite, in the vicinity of Princeton, Ky. U. S. National Museum Nos. 64834, a, b.

7. Pedicle view of a species agreeing in essential features with figures 5 and 6. Zone 4 of the Ohara member of the Ste. Genevieve limestone, Cedar Hill, near Princeton, Ky.

8. Pedicle view of another specimen from the same bed and locality as the preceding. This specimen agrees more closely with the typical form of the species represented by figures 10 and 12. The same variety is found also in the Fredonia oolite member. U. S. National Museum Nos. 64835, 64835a.

9. Pedicle view of a specimen of the variety of the relatively only moderately convex variety of the species. This specimen agrees in every essential feature with the Fredonia limstone specimen shown in figure 4. From the Gasper oolite near New Bethel, Meade County, Ky. U. S. National Museum No. 64838.

10–12. Pedicle views of three examples of the typical form of the species. From the Gasper oolite, Meade County, Ky. U. S. National Museum Nos. 64839, a, b.

13. Specimen of a variety that is common in the Gasper oolite —and so far as known confined to it—in Meade County, Ky., and elsewhere. It differs from the typical form of the species in being less transverse and in having a deeper and more sharply impressed sulcus and finer striations. U. S. National Museum No. 65025.

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DESCRIPTION OF PLATE 4.

Chester Productidae of the Genus Diaphragmus.

Diaphragmus elegans is properly regarded by paleontologists generally as one of the most characteristic as well as abundant fossils of the Chester series. Broadly conceived as it is in common practice, the species may be said to range almost if not quite from the base to the top of the series. However, as indicated by these figures and notes, critical comparisons of extensive collections show that in passing from the Fredonia to the Ohara, and from this again into the Gasper, various small differences in either average expression or relatively unimportant structural features obtained. Taking these into account, the several Monte Sana occurrences commonly are definitely distinguishable. When we come to the Birdsville stages of the species a more important difference becomes notable. This is in the relative distance from the beak of the brachial valve at which the internal diaphragm diverges from the outer wall of the valve. Measurements of many specimens show that in the Monte Sana forms, that is in those found in the Fredonia, Ohara, and Gasper horizons, the length of the inner disk, measuring from the beak of the brachial valve, is about 9 or 10 millimeters and the width of the diaphragm about 3 millimeters. In the Birdsville examples, on the contrary, corresponding measurements give 7.5 to 8.5 millimeters and 13 to 15 millimeters, respectively. In other words the diaphragm is constantly nearly twice as wide in the Birdsville forms as in the Monte Sana varieties.

Now, while there seems no valid reason to doubt the specific identity of the Fredonia, Ohara, and Gasper specimens of Diaphragmus, the structural difference just mentioned as distinguishing the Birdsville specimens is of a kind that should be recognized in systematic paleontology. And this desirability is emphasized when we consider the purposes of stratigraphic paleontology and the consequent need of nomenclatural means by which one may refer definitely to the guide fossils. Accordingly, and in view of the fact that the name *elegans* was given by Norwood and Pratten to the Birdsville form, and that Worthen's substitute *cestriensis* also included, at least primarily if not solely, the younger of the two varieties, a new designation—*Diaphragmus montesanae*—is proposed for the older form. McChesney's *Productus fasciculatus* may be a variety of either, but more probably of *Diaphragmus elegans*.

The distinguishing characteristics of *Diaphragmus elegans* are clearly shown in Norwood and Pratten's original illustrations of the species, and even better in those published by Weller (The Mississippian Brachiopoda, Illinois Geol. Survey, Mon. 1, 1914, pl. 12, figs. 8–17, especially fig. 14).

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Figs. 1–8. *Diaphragmus montesanae* Ulrich, n. sp. Specimens from the Fredonia member of the Ste. Genevieve limstone.

1–4. Pedicle views of four silicified specimens, from the main cherty bed of the Fredonia oolite, in railroad cut northwest of Cerulean Springs, Ky. U. S. National Museum Nos. 65026, a, b, c.

The Fredonia representatives of the species mostly conform to the type of the broad variety in which the antero-median part of the valve is flattened and in some instances even slightly sulcate. Indistinguishable forms occur in the upper Ohara but in these higher zones the narrower form of the species is at places equally abundant. In the succeeding Gasper oolite the latter is strongly dominant and its plications, moreover, fewer and correspondingly stronger.

5–8. Brachial views of four other specimens from the Fredonia at the same place. U. S. National Museum Nos. 65026d-g.

In all of these specimens the relatively smooth band along the lateral and anterior sides represents the inner diaphragm that distinguishes species of this genus from *Productus* as now understood. As is commonly the case, the thin anterior parts of the valves are broken away (see figs. 14 and 16). In perfect specimens the brachial valve is deeply concave on the outer side.

Figs. 9–24. *Diaphragmus montesanae*. Specimens from the Ohara member of the Ste. Genevieve limestone.

9–12. Pedicle views of four specimens of the wide form of the species from zone 3 of the Ohara at Moore's glade, about 5 miles WSW. of Marion, Ky. U. S. National Museum Nos. 65027, a-c.

The pedicle views of these specimens are practically indistinguishable from those of the Fredonia form of the species.

13. Another shell from Moore's glade, representing the relatively narrow and more evenly convex variety of the species. U. S. National Museum No. 65030.

14, 15. Brachial sides of yet other specimens from the same bed and locality, representing respectively the broad and narrow varieties. Figure 14 retains most of the marginal part of the brachial valve, the diaphragm being exposed only for short distances beneath the cardinal angles. In figure 15, as usual, the anterior edges of the valves are broken away at the plane of the diaphragm. U. S. National Museum Nos. 65027d, 65028.

16. Edge view of an incomplete example from the same bed and place, broken so as to indicate the contour of the

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inner surface of the brachial valve. The contour of the pedicle valve is indicated by a dotted line. U. S. National Museum No. 65029.

17, 18. Pedicle views of two specimens of the broad variety from zone 2 of the Ohara member at Cedar Hill, near Princeton, Ky. U. S. National Museum Nos. 65031, a.

These specimens indicate the extremes of variation in relative size of the radial plications so far observed among Ste. Genevieve specimens. These are coarsest in figure 24 which agrees very well with some of the specimens found in the Gasper oolite. (Compare with figs. 27 and 28.)

Figs. 25–31. *Diaphragmus motesanac.* Specimens from the Gasper oolite.

25. Pedicle view of a broad specimen from Lambs Cut, 3 miles east of Scottsburg, Ky. This variety is relatively rare in the Gasper oolite. U. S. National Museum No. 65033.

26–29. Pedicle views of four specimens of the narrow, typical variety of the species; from the same bed and locality. These figures show observed variations in relative coarseness of radical plications, these being as a rule stronger than in the preceding Ohara and Fredonia occurrences. U. S. National Museum Nos. 65034, a-c.

30, 31. Brachial views of two other specimens from Lambs Cut, the first of the broad and the other of the narrow variety. Like figures 5–8 and 15, these specimens lack the anterior edges of the valves, the relatively smooth border being the interior diaphragm. U. S. National Museum Nos. 65035, 65036.

Figs. 32–40. *Diaphragmus elegans* (Norwood and Pratten).

32. Longitudinal section of a specimen from a Birdsville formation at Chester, Ill., showing the internal diaphragm at D.

33, 34. Profile and brachial views of a specimen that retains a part of the outer wall of the brachial valve. Okaw limestone, near Evansville, Ill.

35, 36. Pedicle and brachial sides of a wider specimen from the same bed and place. As usual the outer wall of the brachial valve is broken away so as to expose the full width of the diaphragm which, as is readily seen, is much wider than in the Monte Sana species of the genus.

37, 39. Similar views of a rather coarsely ribbed mutation. Glen Dean limestone, Breckinridge County, Ky.

39, 40. Pedicle and profile views of a specimen of the narrow variety of this species. The characters of the surface are well preserved, among them the bases of the tubular spines.

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DESCRIPTION OF PLATE 5.

Pentremites of the Gasper Oolite.

Figs. 1–13. *Pentremites planus* Ulrich, n. sp.

1–5, 10. Side views of six specimens from the lower to middle part of the upper Gasper division of the Monte Sana oolite near Cowan, Tenn. Figures 4 and 5 indicate observed extremes in relative obesity. The posing of figure 10 is not as vertical as intended. The top of the crown is tilted into the field of vison and the base, which ought to show as in figure 1, is hidden behind the lowered extremity of the anterior ambulacral area. U. S. National Museum Nos. 64800, 64800a, b, c, e.

6–9. Four specimens from the Paint Creek formation on Prairie du Long Creek, 1.5 miles northwest of Floraville, St. Clair County, Ill. Springer collection, U. S. National Museum.

11–13. Similar views of three specimens from the upper member of the Gasper oolite near Bowling Green, Ky. U. S. National Museum No. 64799.

This species has hitherto been confused with *P. godoni* which also is found very abundantly and, so far as known, only in the Gasper oolite in Kentucky and in equivalent deposits elsewhere. *P. planus* attains larger dimensions and is otherwise readily distinguished by the transverse flatness of the upper half or more of its ambulacral areas. In true *P. godoni* the two halves of these areas slope inward toward the median line.

It hardly needs to be pointed out that the Paint Creek specimens are precisely like those from the upper division of the Gasper in Kentucky and Tennessee. *P. planus* is found also in the lower member of the Gasper but these older specimens commonly are smaller than those found in the upper member and in the Paint Creek formation.

Figs. 14–16. *Pentremites planus* var.

14, 15. Two specimens from the locality near Cowan, Tenn., representing a widely distributed variety differing from the typical form of the species in having the two halves of the ambulacral areas gently convex throughout growth instead of flat in the upper half or two-thirds. As a rule, too, the base is slightly more prominent. In both respects this variety approaches *P. biconvexus*. U. S. National Museum No. 64803.

16. Anterior view of an excellent specimen of the same variety from the Paint Creek formation, near Floraville, Ill.

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Springer collection U. S. National Museum. This specimen matches the Tennessee specimen shown in figure 14 very closely.

Figs. 17–30. *Pentremites godoni* DeFrance (fig. 23).

17–22, 25. Side views of seven specimens forming a series selected to show variations marking normal stages in growth from young to complete maturity. Limestone representing the Gasper in the Monte Sana limestone, near Huntsville, Ala. Springer collection, U. S. National Museum.

23. A unique specimen from the Paint Creek formation, near Floraville, Ill., probably representing a distinct variety in which the base as a whole is higher and the basal plates more swollen than in any of thousands of specimens of the typical form of the species found in places to the south of Ohio River. Springer collection, U. S. National Museum.

24. Another specimen from the Paint Creek, near Floraville, Ill. This matches Alabama specimens, especially figures 19, 20, and 22, very well. Springer collection, U. S. National Museum.

26–30. Five specimens from the upper division of the Gasper oolite at Lambs Cut, 3 miles east of Scottsburg, Ky. U. S. National Museum Nos. 64806, a, b, c, d.

Figs. 31–33. *Pentremites decipiens* Ulrich, n. sp.

31, 32 Rather young and a medium-sized specimen, found associated with *P. planus* and *P. pyriformis* near Cowan, Tenn. U. S. National Museum Nos. 64823, 64823a.

33. Anterior view of a larger specimen from the same bed and place. At the passage from the base to the left interambulacral space is a low ridge that is not observable in the other interradial spaces and is entirely absent on the other specimens. Springer collection, U. S. National Museum.

This rather rare species seems to be an aberrant member of the group of *P. pyriformis*, with more or less obvious relations to *P. girtyi*, *P. patei*, *P. buttsi*, *P. abruptus*, *P. welleri*, and *P symmetricus*. From the first and second of these it is distinguished by its relatively shorter and more pedunculate base, from the third by its more concave interambulacral spaces and less slender form, from the fourth, fifth, and sixth by its gently concave instead of more or less distinctly convex ambulacral areas, thinner poral pieces, and smaller size. Pehaps even closer affiliations are indicated on comparison with *P. arctibrachiatus* var. *huntsvillensis*. Still, viewed from the standpoint of genesis, the relations of this case seem more apparent than real, *P. arctibrachiatus* being a mem-

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ber of the group of *P. godoni*. It, as well as the variety *huntsvillensis*, is at once distinguished from *P. decipiens* by its smaller poral pieces. Finally, *P. decipiens* is related, probably genetically, to species of the group of *P. canalis*, like *P. springeri*, *P. elegans*, and *P. cervinus*, but in all of these the base is relatively higher. It is found in the Paint Creek formation in Illinois, and in the upper division of the Gasper oolite in Kentucky, Tennessee, and Alabama.

Figs. 34, 35. *Pentremites decipiens* var. *decurtatus* Ulrich, n. var.

The types of this variety. They were found respectively in the Gasper oolite in Breckinridge County, Ky., and in the corresponding part of the Monte Sana limestone, near Cowan, Tenn. U. S. National Museum Nos. 64824, 64825.

This variety is distinguished from the typical form of the species by its shorter and thicker basal extremity. The lower part of the pelvis and, indeed, the general aspect of the head as a whole reminds of *P. symmetricus* Hall, but on further comparison the ambulacral areas are found to differ in being flat or shallowly canaliculate instead of distinctly convex. Besides, the poral pieces are relatively smaller and more numerous.

Figs. 36–40. *Pentremites springeri* Ulrich, n. sp.

Five specimens, four of them showing the sides and one the crown, from the upper division of the Gasper oolite, near New Bethel, Breckinridge County, Ky. Springer collection, U. S. National Museum.

The young of this species, as for instance figure 37, often reminds of those of *P. canalis*, a Birdsville species, but the basal extremity commonly is thicker, indicating a heavier column, the sides of the pelvis are more concave, and the crown relatively shorter and more inflated, especially in old examples, the form as a whole, therefore, being more pear-shaped. Further, the two halves of the ambulacral areas are more convex. In all of these peculiarities the species reminds of the gigantic *P. obesus* Lyon, one of the best of the guide fossils of the Golconda shale, and which may have been developed out of *P. springeri*.

Collections in the U. S. National Museum indicate at least three varieties of *P. springeri* in the Gasper oolite. One, the typical form, is figured on this plate. The second has much the same form but more deeply channeled ambulacra. In the third variety the ambulacral areas are less deeply excavated and the crown

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but slightly inflated. The last approaches *P. girtyi* in some respects and *P. decipiens* in others. The first of these is widely distributed and locally found in abundance in Kentucky and east Tennessee, and also in the Renault formation in Monroe County, Ill. The second has been found only in Breckinridge County, Ky., whereas the third commonly is found associated with the first.

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DESCRIPTION OF PLATE 6.

Pentremites of the Gasper Oolite.

Figs. 1–9. *Pentremites pyriformis* Say.

1–5. Side views of a series of five specimens, ranging from young to a moderately old stage of growth; from the *Pentremites* bed in the upper half of the Monte Sana limestone, near Huntsville, Ala. Springer collection, U. S. National Museum.

6, 8. Two rather large specimens from the Gasper oolite near Bowling Green, Ky. Springer collection, U. S. National Museum.

7. A very large specimen from the vicinity of Huntsville, Ala. Springer collection, U. S. National Museum.

9. A doubtfully identified specimen from Huntsville, Ala., with the upper extremity somewhat narrower and the base more attenuate than usual. In the features mentioned it suggests *P. welleri*. Springer collection, U. S. National Museum.

The characteristic features of the typical form of the species are the thick flat-sided plates, somewhat obtuse crown, gently convex ambulacral areas, and rather coarse poral pieces. This exact combination of characters has been found only in the Gasper and equivalent limestones to the south and east of Illinois. In places, particularly northern Alabama, it is very abundant. It is still rather common in the vicinity of Bowling Green, Ky., but is rather rare in western Kentucky; and exactly identifiable specimens have not been found in southwestern Illinois at all. But the species is not entirely unrepresented there, there being in the Springer collection at least one specimen from the Renault and three specimens from the Paint Creek formation of a small variety in which the pelvis is relatively slightly lower than in the typical form of the species. The same variety is found in the Gasper oolite in Kentucky and Alabama.

The large number of specimens now in the U. S. National Museum, mainly in the Springer collection, indicate at least three other more or less easily recognizable and widely distributed varieties of this species.

Figs. 10–14 *Pentremites abruptus* Ulrich, n. sp.

10. Rather small but typical specimen from the Gasper part of the Monte Sana limestone, near Huntsville, Ala. U. S. National Museum No. 64819.

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11. Lateral view of the type of the species. Associated with *P. planus* and *P. pyriformis* in the Gasper part of the Monte Sana limestone, near Cowan, Tenn. U. S. National Museum No. 64818.

12, 13. Two large specimens from the same bed and place as figure 10. Springer collection in U. S. National Museum. In the second of these the right posterior ray, shown in middle of figure—and to a less extent also the right anterior—is abnormal in that the lower extremity of the ambulacral area is moved upward about 2 millimeters above the position held in earlier life.

14. A small but fairly typical specimen from the Paint Creek formation on Prairie du Long Creek, 1.5 miles northwest of Floraville, Ill. Springer collection, U. S. National Museum.

As shown in these figures, *P. abruptus* differs from *P. pyriformis* in having a shorter pelvis, constricted below to a subcylindrical pedicle. The species is not very common at any known place but is widely distributed in the Gasper oolite and corresponding deposits, being represented in the U. S. National Museum by a total of some 50 specimens from Huntsville, Ala., Cowan and Sneedsville, Tenn., western Kentucky, and from three localities in southwestern Illinois. Some of the Cowan specimens are more slender than those here illustrated, and nearly half of the total number belongs to a variety differing from the typical form in having flat or slightly concave instead of convex ambulacral areas and a somewhat shorter peduncle. Whereas the typical form seems to be rare in the Renault of Illinois, the variety mentioned is about equally common in the Renault and Paint Creek formations on the one hand, and the upper part of the Monte Sana in east Tennessee on the other.

Figs. 15–26. *Pentremites welleri* Ulrich, n. sp. and varieties.

Side views of twelve specimens, showing some of the variations included in this species; all except figure 21 in the Springer collection, U. S. National Museum; figures 15, 16, 23, 25, and 26 may be designated as the typical form, figures 17 and 18 represent a variety in which the ambulacral areas are flat or slightly concave in the upper third, figures 19–22 represent a slender variety in which, moreover, the basal plates tend to become slightly protuberant, and, finally, figure 24 represents an obese variety or merely an old specimen in which the upper part of the pelvis expands more rapidly and to a greater extent than usual.

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Specimens 15, 16, 20, 22, 23, 24, 25, and 26 are from the Gasper part of the Monte Sana limestone, near Huntsville, Ala. Specimens 17 and 18 are from the Gasper oolite, near Bowling Green, Ky. Specimen 19 is from the Renault formation, near Floraville, Ill. Specimen 21 is from the Paint Creek formation in Monroe County, Ill., and now in the U. S. National Museum No. 64830.

All of these specimens agree among themselves and differ from *P. pyriformis* in having thinner plates, concavely outlined pelvis, and gently concave interambulacral spaces. The species is related to *P. symmetricus* but differs in its longer pelvis and attenuated base.

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DESCRIPTION OF PLATE 7.

Pentremites of the Gasper Oolite and Glen Dean Limestone.

Figs. 1–7. *Pentremites gemmiformis* Hambach.

1. Lateral view of Hambach's original type of this species. Springer collection, U. S. National Museum. The accessory deposit forming the beadlike base is extravagantly developed in this specimen. Other specimens referred at the same time to this species by Hambach are almost perfectly matched by examples here illustrated. The type is from the Chester (probably Paint Creek formation), north of Evansville, Ill.

2–7. A series of six specimens selected to show growth stages. The originals of 2–5 are from the Paint Creek formation on Barbeau Creek, in the northern part of Randolph County, Ill. Springer collection, U. S. National Museum Those of 6 and 7 are from the upper member of the Gasper oolite at Lambs Cut, 3 miles east of Scottsburg, Ky. U. S. National Museum Nos. 64833, 64833a.

So far as known *P. gemmiformis* is confined to the upper limestone member of the Gasper in Kentucky and to corresponding beds of the Paint Creek formation in southwestern Illinois.

Figs. 8–10. *Pentremites symmetricus* Hall.

8. Antero-lateral view of a large specimen from the Paint Creek formation on Barbeau Creek in northern part of Randolph County, Ill. Springer collection, U. S. National Museum.

9. Left posterior view of a smaller but quite typical example from the Paint Creek formation, near Waterloo, Ill. U. S. National Museum No. 64814. As the specimen originally figured by Hall seems to be lost, it is proposed to substitute this specimen as the type of the species.

10. A well-preserved, large and typical example, from the Renault formation, near Floraville, Ill. Springer collection, U. S. National Museum.

As here re-established, *P. symmetricus* is characterized by its distinctly convex ambulacral areas, relatively short pelvis, small basal bead, somewhat convex basal plates, and gently concave interambulacral spaces. Most of these features distinguish it from *P. pyriformis* and *P. abruptus*, to both of which it is somewhat remotely related. A much closer relative is found in *P. welleri* from which it differs mainly in its shorter pelvis. In its general aspect it reminds considerably of *P. decipiens*, and especially of the variety *decurtatus*, but

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those forms are readily distinguished by their gently concave, instead of convex, ambulacra and their smaller poral pieces.

P. symmetricus is a common fossil in both the Renault and the Paint Creek formations in southwestern Illinois. South of the Ohio it is found in the Gasper oolite but never abundantly.

Figs. 11–16. *Pentremites girtyi* Ulrich, n. sp.

A series of specimens of the typical form ranging from young to old. At the right of the top of figure 15, which may be designated as the holotype, is an outline sketch indicating the contour in transverse section of one of the ambulacral areas. All of these are but a few of 100 or more specimens from a rich pentremital bed in the Gasper oolite—presumably in the upper member—near New Bethel, in Breckinridge County, Ky. Springer collection, U. S. National Museum.

P. girtyi probably was derived out of *P. pyriformis*, and later perhaps passed into the Birdsville species, *P. canalis*. This is suggested by the intermediate structure of its ambulacral areas and intermediate size of its poral pieces, coupled with a general agreement in the form of their respective pelves.

Besides Breckinridge County, this species has been found in the Gasper oolite in Todd and Caldwell counties, Ky., also in the Maxville limestone at Newtonville, Ohio, and in the Paint Creek formation in Monroe County. Ill.

Figs. 17–22. *Pentremites patei* Ulrich, n. sp.

A series of seven specimens, figure 17 being of an old individual, and figure 22 of a young one. The outline sketch at the right of the top of figure 18 shows the flatness of the ambulacral areas that constitutes the main difference between this and the preceding species. Comparison of the figures shows, further, that in *P. patei* the angle of divergence of the pelvis is slightly greater and its height relatively less than in *P. girtyi*. The two species are associated and about equally abundant in Breckinridge County, Ky., where the figured specimens, now in the Springer collection at the U. S. National Museum, were collected.

P. patei is further represented in the collections at the U. S. National Museum by specimens from places in Todd and Caldwell counties, Ky., Monroe County, Ill., and near Huntsville, Ala.

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Figs. 23–26. *Pentremites canalis* Ulrich, n. sp.

23. View of the left side of a well-preserved but rather young head.

24. Anterior view of another even younger specimen.

25. Right side of the largest specimen seen. It is imperfect at the base but the remainder is sufficiently preserved to indicate how the fully matured stage differs from the immature.

26. View of the crown of a fourth specimen. This is intermediate in size between figures 23 and 24.

All of these specimens (paratypes) were collected from shaly beds of the Glen Dean limestone taken out of the tunnel at Sloans Valley, Ky. Ulrich collection, U. S. National Museum, Nos. 64836, a, b, c.

P. canalis is a widely distributed and characteristic fossil of the Birdsville group, in which it is found mainly if not entirely in the Glen Dean limestone. Besides the typical form, two or three good varieties will be distinguished when the contemplated monograph on the genus *Pentremites* is published. The species is characterized by its rather rapidly expanding pelvis, nearly flat interambulacral spaces, rather low, rounded crown, and broadly V-shaped, flat-sided, ambulacral areas. This combination of characters distinguishes it from its Gasper allies, *P. patei* and *P. girtyi*. Compared with Birdsville species it reminds of *P. cervinus* Hall, in which the head is relatively broader, the base blunter, and the ambulacral areas less deeply excavated; and of *P. angularis*, in which likewise the head is broader whereas the ambulacra are deeper and the tips of the deltoid plates more erect and prominent.

Figs. 27–29. *Pentremites lyoni* Ulrich, n. sp.

27. Right posterior view of the holotype; Golconda formation, Pickering Hill, 7 miles north of Marion, Ky. Ulrich collection, U. S. National Museum No. 64837.

28. Right anterior view of another typical specimen from the same bed, place, and collection No. 64837a.

29. Left posterior view of a variety with longer pelvis, smaller deltoids, and ambulacra slightly concave at the top. Glen Dean limestone, Sloans Valley, Ky. Springer collection, U. S. National Museum.

This species is related to *P. welleri* and probably was derived from it. They are constantly distinguished by the narrow and therefore more numerous poral pieces in the Birdsville species.

P. lyoni is found at many localities in Alabama,

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Georgia, Tennessee, Kentucky, and Illinois. In Randolph County, Ill., it is found in the lower and perhaps higher parts of the Okaw limestone. In and to the south of the Ohio valley it occurs mainly in the Golconda formation but varieties extend upward into the Glen Dean limestone.

Figs. 30–32. *Pentremites lyoni* var. *gracilens* Ulrich, n. var.

30. A very slender specimen that may be viewed as the type of this variety. Golconda formation, Golconda, Ill. U. S. National Museum No. 64840.

31. A younger example from either the Golconda or the Glen Dean limestone, in the northwestern part of Meade County, Ky. Ulrich collection, U. S. National Museum, No. 64839.

32. An older specimen with uncommonly attenuated base, from the same bed, place, and collection as figure 31. No. 64839a.

This variety is distinguished by its slender form and proportionately longer pelvis. It is represented in the U. S. National Museum by specimens from the Golconda formation at several localities in western Kentucky, and at Golconda, Ill., by others from the Okaw limestone in Randolph County, Ill., and by yet others from a lower Birdsville horizon at Bangor, Ala.

Figs. 33–35. *Pentremites spicatus* Ulrich, n. sp.

Left anterior, crown, and basal views of the type of this species. Cherty beds of the Glen Dean limestone, Grayson County, Ky. Springer collection, U. S. National Museum.

This species belongs in a section of the genus comprising also *P. sulcatus*, *P. basilaris*, *P. cherokeeus*, and *P. serratus*. All of these are confined to rocks of the Birdsville group, and all of them are variable in character. The available material of *P. spicatus* likewise is divisible into three or four varieties, differing from each other in the relative height of the pelvis, in the shape of the calyx, and in minor details of structure. All of these, however, are characterized by relatively narrow ambulacral areas, and usually by extreme prominence of the tips of the deltoid plates. So far as known the species is confined to the Glen Dean limestone in which it is found in Grayson and Breckinridge counties, Ky., and near Dover Hill, Ill.

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DESCRIPTION OF PLATE 8.

Lower Chester Species of Talarocrinus.

Figs. 1–4. *Talarocrinus buttsi* Ulrich, n. sp.

1. Photograph of left side of holotype. Zone 2 of the Ohara member of the Ste. Genevieve limestone, 1 mile north of courthouse at Princeton, Ky. Collected by Charles Butts after whom the species is named. U. S. National Museum No. 64827.
8. Drawing of posterior side of same, x 1.4.
3. View of top of same, x 1.4.
4. Base of same, x 1.4.

The obconical form of the pelvis suggests *Dichocrinus*, but the plates are too thick for that genus and the characters of the tegmen are like those of *Talarocrinus* and not *Dichocrinus*. Specifically *T. buttsi* reminds strongly of *Dichocrinus huntsvillae* from the *Platycrinus* bed of the Ste. Genevieve at Huntsville, Ala. Critically compared, however, it is soon established that the Princeton fossil is really quite distinct. That species has two costals whereas this has but one, and it is small and clearly axillary. The pelvis also is more broadly obconical in *T. buttsi*.

On comparison with associated and later species of *Talarocrinus* this new species is readily distinguished not only by the more gradual taper of its basal part but also by the distinctness of the anal tube and the relative lowness and general reduction of the lobes of the tegmen. Its nearest ally seems to be the next following species, *T. dewolfi*, which also is characteristic of the upper part of the Ohara.

Figs. 5–10. *Talarocrinus dewolfi* Ulrich, n. sp.

5, 6. Views of the right side and base of a specimen of this species. Zone 3 of the Ohara, 2 miles north of Cerulean Springs, Ky., where many specimens were found. U. S. National Museum, No. 64828.

7, 8. A drawing and an untouched photograph of the top of same, x 1.4.

9, 10. Retouched photographs of the posterior and anterior sides of same, x 1.4.

These illustrations show the characters of this species and leave no room for doubt regarding its distinctness from *T. buttsi*. Its distinctness from *T. trijugis*, however, is not so obvious. Still, on comparison with the original figures of that species and with specimens referred to it, it appears that the calyx in *T. dewolfi* is

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smaller and not nearly so broad as in *T. trijugis*. The relatively inferior width, in so far as the pelvis is concerned, affects not only the radial plates but also the basals which show to greater height and are more rounded below in a side view. Besides, the outer surface of the pelvic plates is not so tumid and the depression in the base is shallower and altogether smaller than in *T. trijugis*. Finally, the tegmen is less distinctly lobate and probably differs in details unappreciated at present. All of these differences are as clearly demonstrated on young specimens of *T. trijugis* as on the mature.

T. dewolfi also is closely related to *T. ovatus*, a Renault and Gasper oolite species. The main differences lie in the tegmen, this being more distinctly lobate, the anal area more tumid, and the nodes or spines and the plates on the top surface smaller and more numerous in the former than in the latter.

The species is named for Mr. Frank DeWolf, State Geologist of Illinois, who has taken a lively interest in the many difficult problems of Chester stratigraphy.

Figs. 11–13. *Talarocrinus trijugis* Miller and Gurley.

Anterior, top, and basal views, after Miller and Gurley. Ste. Genevieve ("St. Louis") limestone, near Rosiclare, Ill. The exact stratigraphic position of the bed from which this specimen was collected is unknown but is most probably in the upper part of the Ohara member. In the vicinity of Princeton the species is found in both zones 2 and 4 of the Ohara.

Figs. 14, 15. *Talarocrinus inflatus* Ulrich, n. sp.

Views of the right side and base of the type of this species. Renault formation, 4.5 miles southwest of Floraville, Ill. Springer collection, U. S. National Museum.

This fine species has characters allying it to *T. trijugis* on the one hand and to *T. cornigerus* on the other, with preponderance of relations to the former. It differs from both in the greater inflation of the tegmen. From *T. trijugis* it is further distinguished by the smaller plates making up the tegmen, the less deep lobation of the latter, and the lesser prominence of the upper part of the anal tube. From *T. cornigerus* it differs conspicuously in lacking the subcylindrical spines marking the tegmen of that species, and also in the much more symmetrical inflation and less deep lobation of the tegmen. Besides, the plates of the pelvis are more tumid and those around the anal orifice fewer and smaller.

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Figs. 16–17b. *Talarocrinus ovatus* Worthen.

16, 17. The right side and base of a specimen from the lower part of the Gasper oolite in Breckinridge County, Ky., where it and other specimens of this species were found associated with the form described by Miller and Gurley under the name *Talarocrinus patei*. Springer collection, U. S. National Museum.

17a, 17b. Photographic copies of Worthen's figures of the posterior and basal sides of the type of this species. This came from the Renault formation in Monroe County, Ill.

No difference worth mentioning has been found by which the specimens collected in the lower Gasper in Kentucky might be distinguished from the Renault species described by Worthen.

Figs. 18, 19. *Talarocrinus cornigerus* (Shumard).

Views of the right side and base of Shumard's type of this species. Chester series—probably upper part of the Monte Sana limestone—"Buzzard Roost," Franklin County, Ala. Now in the Springer collection, U. S. National Museum. Figured for comparison with *T. inflatus*.

Figs. 20, 21. *Talarocrinus elegans* (Lyon).

Left side and basal views of Lyon's type of this species. Gasper oolite, near Mammoth Cave, Ky. Now in the Springer collection, U. S. National Museum.

This species is related to *T. sexlobatus* (Shumard) and *T. symmetricus* (Casseday and Lyon) but is distinguished by its more depressed form and particularly in wanting the constriction above the radials. The radial angles at the top of the tegmen evidently terminated in small transversely compressed spines.

A specimen apparently of this species was found in the upper part of the Gasper oolite, about 10 miles northwest of Hopkinsville, Ky.

Figs. 22, 23. *Talarocrinus symmetricus* (Casseday and Lyon).

Right side and basal views of the type of this species. Gasper oolite, Russellville, Ky. Springer collection, U. S. National Museum.

This species is characterized by its rather low calyx and constricted subconical tegmen, the medium tubercle of the latter being very prominent and the radial tubercles relatively small. The most important of these features allies it to *T. sexlobatus* but the strong median and weak radial spines on the summit of the tegmen give a conspicuously different aspect to side views, the relative development of these spines being directly the opposite in *T. sexlobatus*. The present species is further distinguished by the more tumid surface of its radial

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plates. A closer relative is found in *T. similis*, an associated new species which holds an intermediate position between *T. symmetricus* and *T. sexlobatus*.

Talarocrinus symmetricus, like its occasional associate, *T. ovatus*, seems to be confined to the lower Gasper in Kentucky and to the Renault in Illinois. In both places they are likely to be found with a smaller species that in its more slender habit reminds of the Ohara species *T. buttsi* and *T. dewolfi*. It is referred to in the text of this paper under the provisional name *Talarocrinus delicatus* Springer MS.

Figs. 24, 25. *Talarocrinus sexlobatus* (Shumard).

Views of the right side and base of the specimen on which Wachsmuth and Springer's revised description of this species is mainly founded. Comparison with Shumard's original type of the species leaves no doubt as to the correctness of Wachsmuth and Springer's identification. Flagpont, Va., in limestone evidently of the age of the Gasper, and not the St. Louis as thought by Wachsmuth and Springer. Springer collection, U. S. National Museum.

Figs. 26, 27. *Talarocrinus elegans* var. *spinigerus* Ulrich, n. var.

The right side and base of the specimen on which this variety is founded. Gasper oolite probably lower member, Breckinridge County, Ky. Springer collection, U. S. National Museum.

The development of strong subcylindrical spines at the radial angles of the top of the tegmen constitutes the only known distinctive feature of this variety. As shown in other views of the specimen, only the bases of these spines remain.

Figs. 28, 29. *Talarocrinus depressus* Ulrich, n. sp.

The right side and base of the type of this species. Lower member of the Gasper oolite, Lambs Cut, 3 miles east of Scottsburg, Ky. Ulrich collection, U. S. National Museum, No. 64798.

The depressed form, hemispherical pelvis, concave anal area, flat top of tegmen, outcurved upper extremities of the radials, and the short, transversely compressed, bladelike angles of the tegmen constitute the distinctive features of this species. In the form of the pelvis the species recalls *T. subglobosus* Wachsmuth and Springer, but the characters of the tegmen are very different in the two species.

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DESCRIPTION OF PLATE 9.

Gasper Oolite Species of Talarocrinus.

Figs. 103. *Talarocrinus ovatus* Worthen.
Retouched photographs of anterior, posterior, and ventral sides of a specimen from the Gasper oolite in Breckinridge County, Ky.; x 2.

Figs. 4–6. *Talarocrinus inflatus* Ulrich, n. sp.
4. Photograph of ventral side of type, x 2.
5, 6. Retouched photographs of posterior and anterior sides of same, x 2.

Figs. 7, 8. *Talarocrinus cornigerus* (Shumard).
Retouched photographs of posterior, anterior, and ventral sides of Shumard's type of this species, x 2.

Figs. 10, 11. *Talarocrinus trijugis* Miller and Gurley.
Photographs, x 2, of the posterior and anterior sides of a large but imperfect specimen of this species. The specimen is partly silicified and in etching it from the limestone matrix some of the plates were destroyed. The median plate of the tegmen seems to have been more prominent than in Miller and Gurley's type of the species. In other respects, however, it appears to agree very well with the type. Zone 4 of the Ohara member of the Ste. Genevieve limstone, north bank of Ohio River, near mouth of Grand Pierre Creek. U. S. National Museum No. 64829.

Figs. 12–16. *Talarocrinus sexlobatus* (Shumard).
12, 13. Anterior and ventral views of the specimen on which Shumard founded this species, x 2. Gasper oolite Russellville, Ky. Springer collection, U. S. National Museum.
14–16. Retouched photographic views of right posterior, posterior, and ventral sides of an uncommonly well-preserved specimen, all x 2. Gasper oolite, Flagpont, Va.

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DESCRIPTION OF PLATE 10.

Talarocrinus of the Gasper Oolite.

Figs. 1–4. *Talarocrinus elegans* (Lyon).

1. Posterior view of Lyon's type of this species, x 2.
2. Drawing of right side of same, x 2.
3, 4. Drawing and untouched photograph of ventral surface of same, x 2.

Figs. 5–7. *Talarocrinus symmetricus* (Casseday and Lyon).

Retouched photographs of the anterior, posterior, and ventral sides of the original type of this species, all x 2.

Figs. 8–13. *Talarocrinus similis* Ulrich, n. sp.

8–10. Anterior, posterior, and basal views of one of the two paratypes; natural size.

11–13. Anterior, posterior, and ventral views of the second paratype; natural size. The basal plates in this specimen are missing. Lower member of the Gasper oolite, Lambs Cut, 3 miles east of Scottsburg, Ky. Ulrich collection, U. S. National Museum, Nos. 64804, 64804a.

As shown by these photographic illustrations, this species is closely allied to *T. symmetricus*. Both species were found in silicified condition in Lambs Cut but their association led to no great difficulty in classifying the specimens. Those of *T. similis* were readily separated by their stronger and sharper radial spines, their depressed anal areas—the depression extending to the upper part of the anal plate—and the less tumid surface of their radials. In the last feature, also in the strength of the radial spines on the tegmen, the new species is like, or at least approaches, *T. sexlobatus*, but the constriction of the tegmen just above the base of the arms is much less, whereas the furrows between the radial lobes of the tegmen are deeper and the relative height of the tegmen is less than in that species.

Figs. 14–16. *Talarocrinus elegans* var. *spinigerus* Ulrich, n. var.

Anterior, posterior, and ventral views, x 2, of the type of this new variety. The specimen is silicified and imperfect on the posterior side. The large spines around the summit of the tegmen also are broken off.

Figs. 17–20. *Talarocrinus depressus* Ulrich, n. sp.

17. Anterior side of the type of this species, x 2.
18. Posterior view of same, x 2, showing the flaring arm facets, the concave anal area, and upwardly directed vent of same; also at the top of the right side one of the compressed spines.

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19. Another similarly magnified view of the posterior side, slightly tilted so as to show the flat top of the tegmen and other features.
20. Ventral view of same, x 2. All but one of the plates at the angles of the tegmen are missing.

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DESCRIPTION OF PLATE 11.

Bryozoa from the Glen Dean Limestone, Gasper Oolite, and Ste. Genevieve Limestone.

Figs. 1–5. *Meekopora clausa* Ulrich.

1. Group of four specimens, natural size. Sloans Valley, Ky., in the Glen Dean limestone, of which it is characteristic. U. S. National Museum No. 64805.

2, 3. Surface magnified 9 and 18 diameters. Most of the zooecial apertures retain the perforated covers.

4. Another specimen from the same place. At the right of the base is a view of its end showing the bifoliate structure of the zoarium. Natural size.

5. Part of the right half of a vertical section, showing the irregularly undulating median lamina on the left, two zooecial tubes, and the vesicular structure of the interspaces, x 18. This is one of the most characteristic fossils of the Glen Dean limestone.

Figs. 6–10. *Chilotrypa hispida* Ulrich.

6, 7. Two fragments of the ramose zoarium of this characteristic Glen Dean bryozoan. Natural size.

8. Tangential section, x 18.

9. Somewhat more than a quarter of a transverse section of one of the stems, showing the rounded axial canal in the upper right half of the figure, x 18.

10. Part of a vertical section of same showing structure of zooecial tubes and interspaces, with the periodically constricted axial tube on right side of figure, x 18.

Figs. 11, 12. *Coeloconus rhombicus* Ulrich.

11. Two specimens of the natural size, and the lower half of one of them, x 12. Ste. Genevieve limestone, near Waterloo, Ill. In Kentucky this species has been found only in zone 3 of the Ohara member.

12. Part of a transverse section of same, x 18.

Figs. 13–15. *Coeloconus granosus* Ulrich.

13. A specimen of the natural size and the greater part of same, x 12.

14. A complete but crushed specimen, natural size.

15. Part of a vertical section showing structure of left wall, x 18.

This species is characteristic of the Gasper oolite in Kentucky and was originally found in beds of corresponding age in Monroe County, Ill.

Figs. 16, 17. *Thamniscus furcillatus* Ulrich.

16. A specimen of the natural size showing the mode of growth commonly pertaining to this species.

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17. A well-preserved fragment of the natural size, and x 9.

This species ranges from the Fredonia member of the Ste. Genevieve limestone to the Glen Dean limestone. It is doubtfully identified also in the Clore limestone.

Except figure 1, all the illustrations on this plate are copied from Ulrich's work in Illinois State Geological Survey, volume 8.

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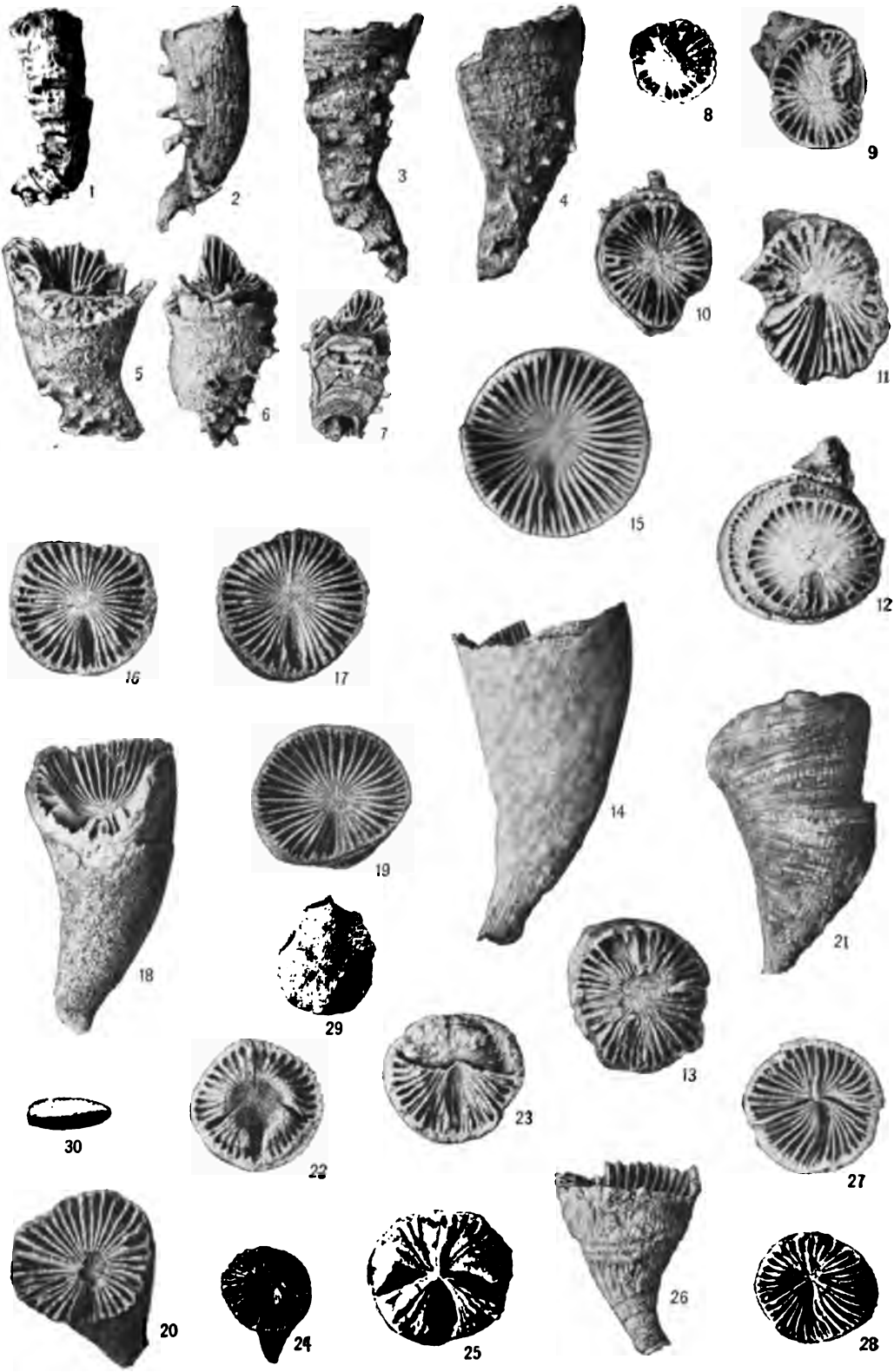

PLATE 1.
Corals of the Ste. Genevieve limestone.

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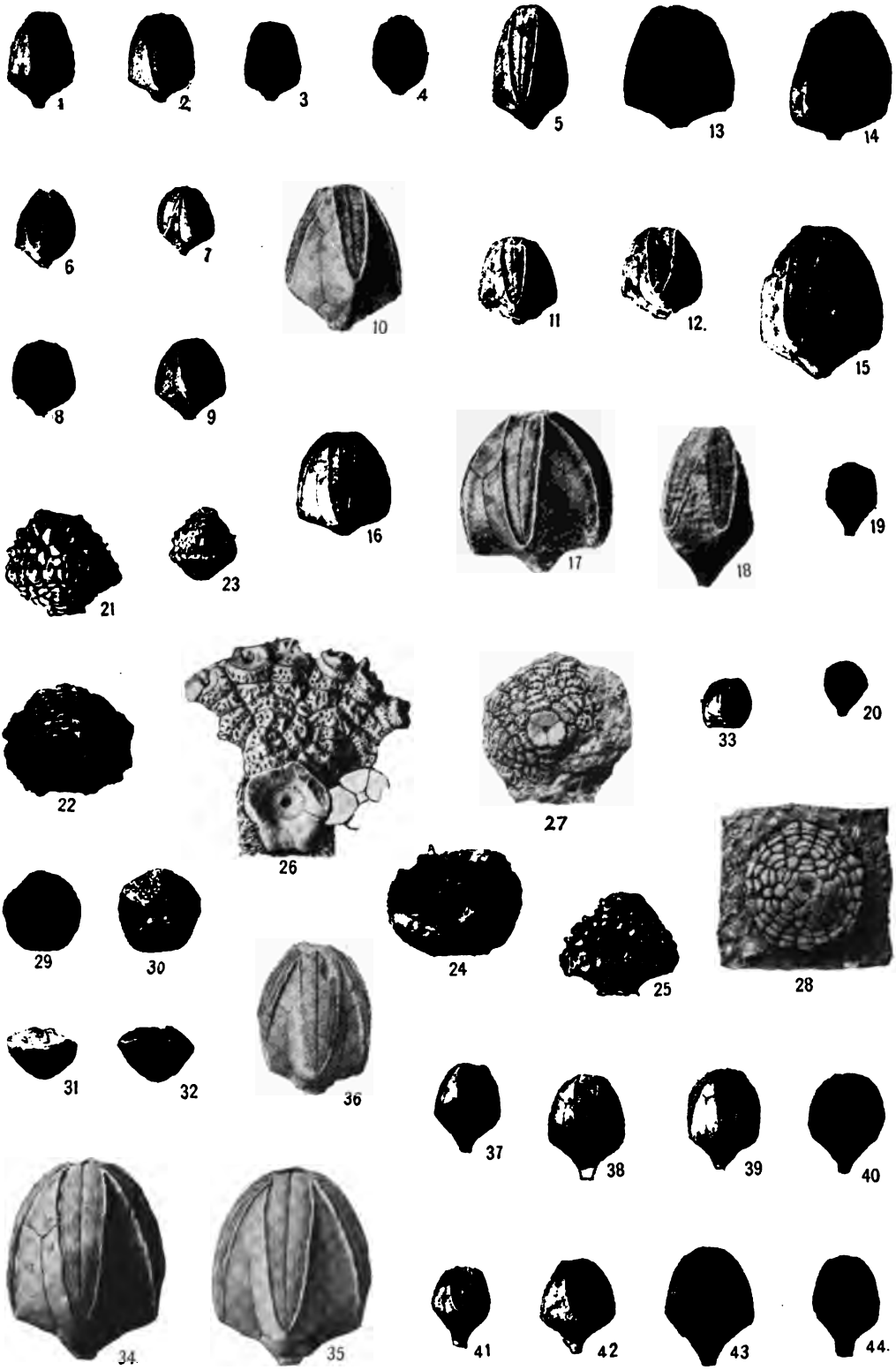

PLATE 2.
Blastoids and crinoids of the Ste. Genevieve limestone and Gasper oolite.

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PLATE 3.

Productidae of the Fredonia oolite.

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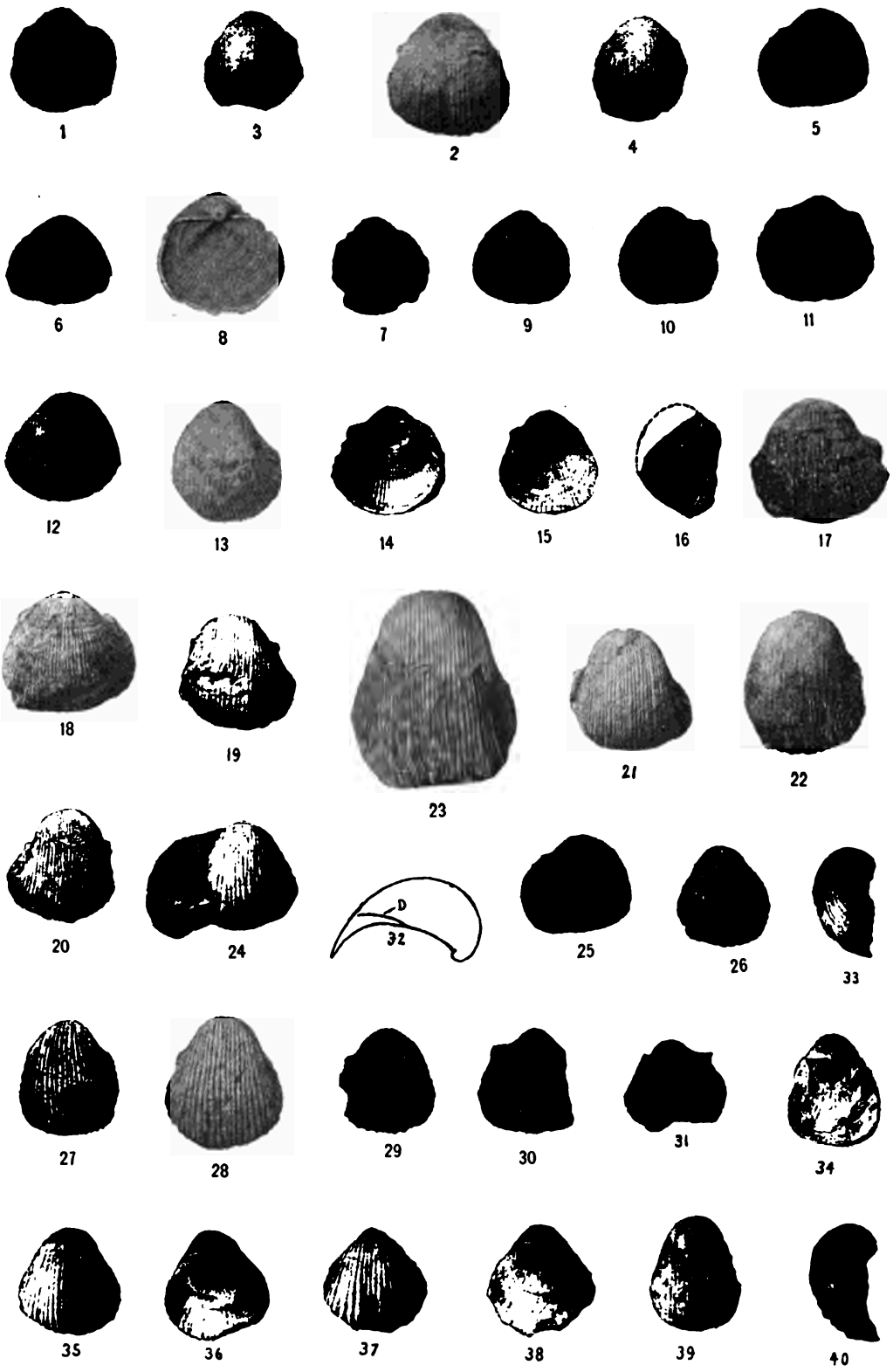

PLATE 4.
Chester Productidae of the genus Diaphragmus.

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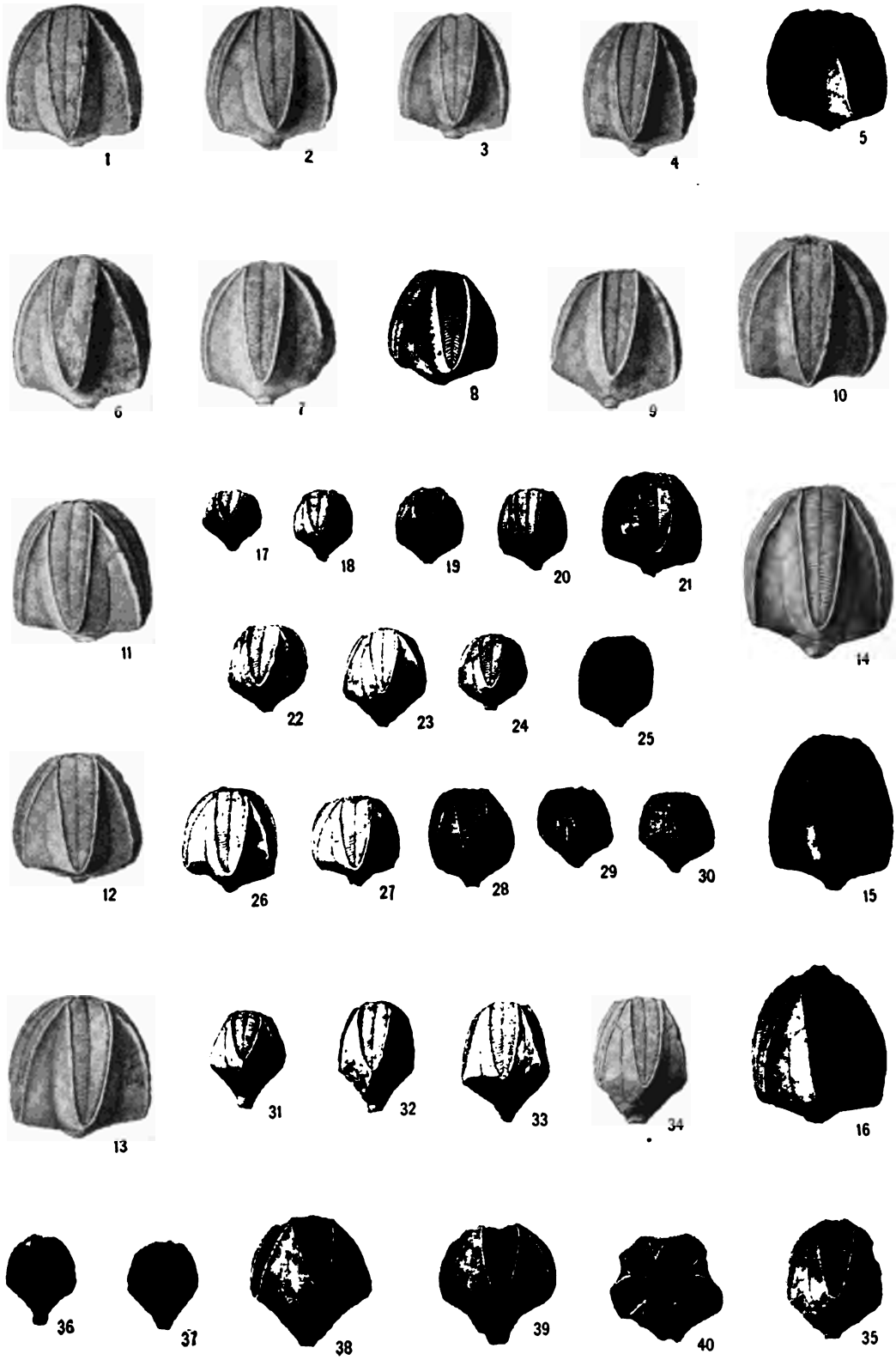

PLATE 5.
Pentremites of the Gasper oolite.

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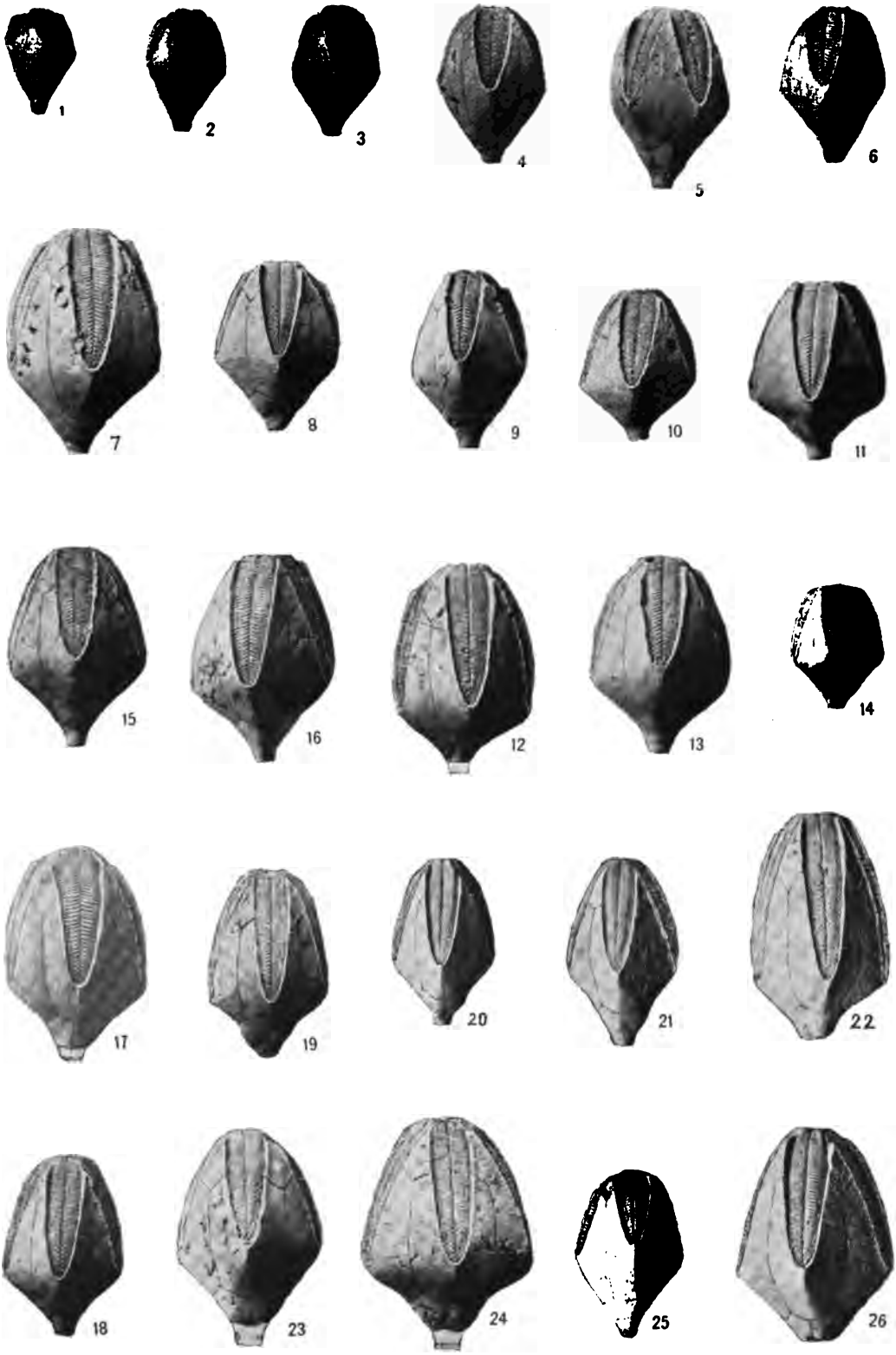

PLATE 6.
Pentremites of the Gasper oolite.

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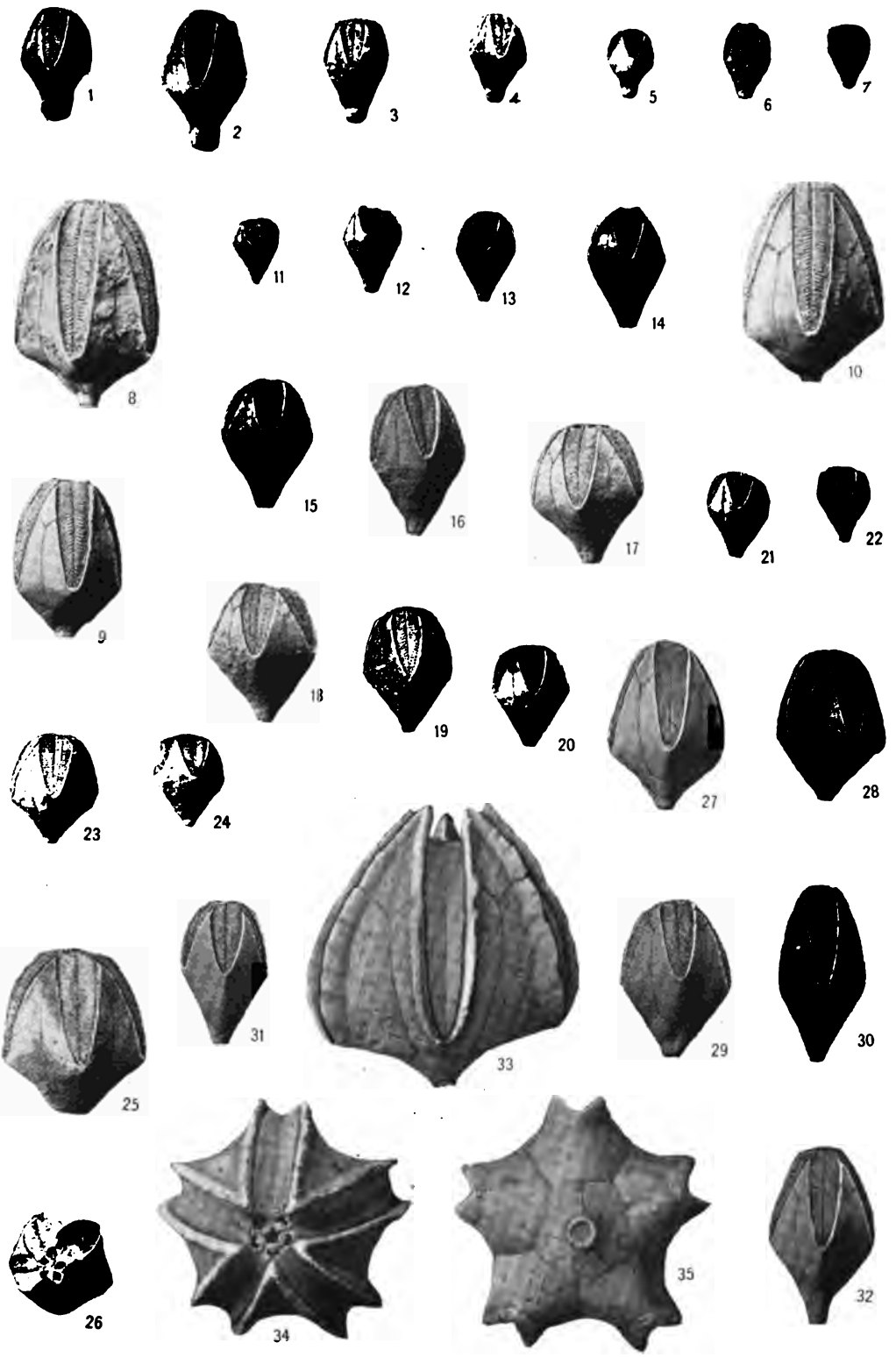

PLATE 7.
Pentremites of the Gasper oolite and Glen Dean limestone.

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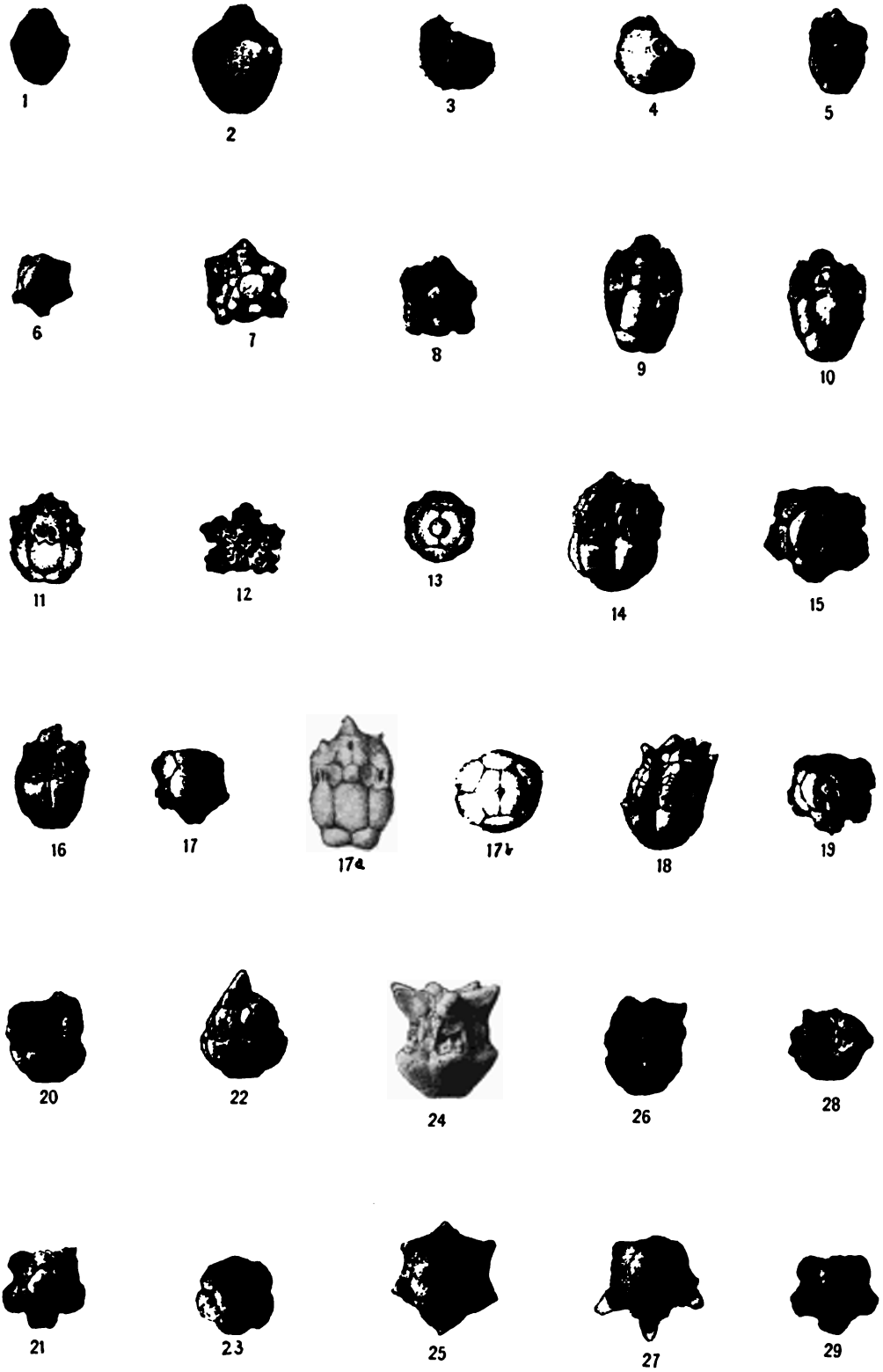

PLATE 8.
Talarocrinus Ste. Genevieve limestone and Gasper oolite.

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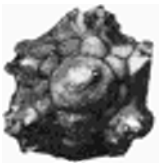

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PLATE 9.
Talarocrinus Gasper oolite.

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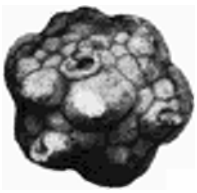
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PLATE 10.
Talarocrinus Gasper oolite.

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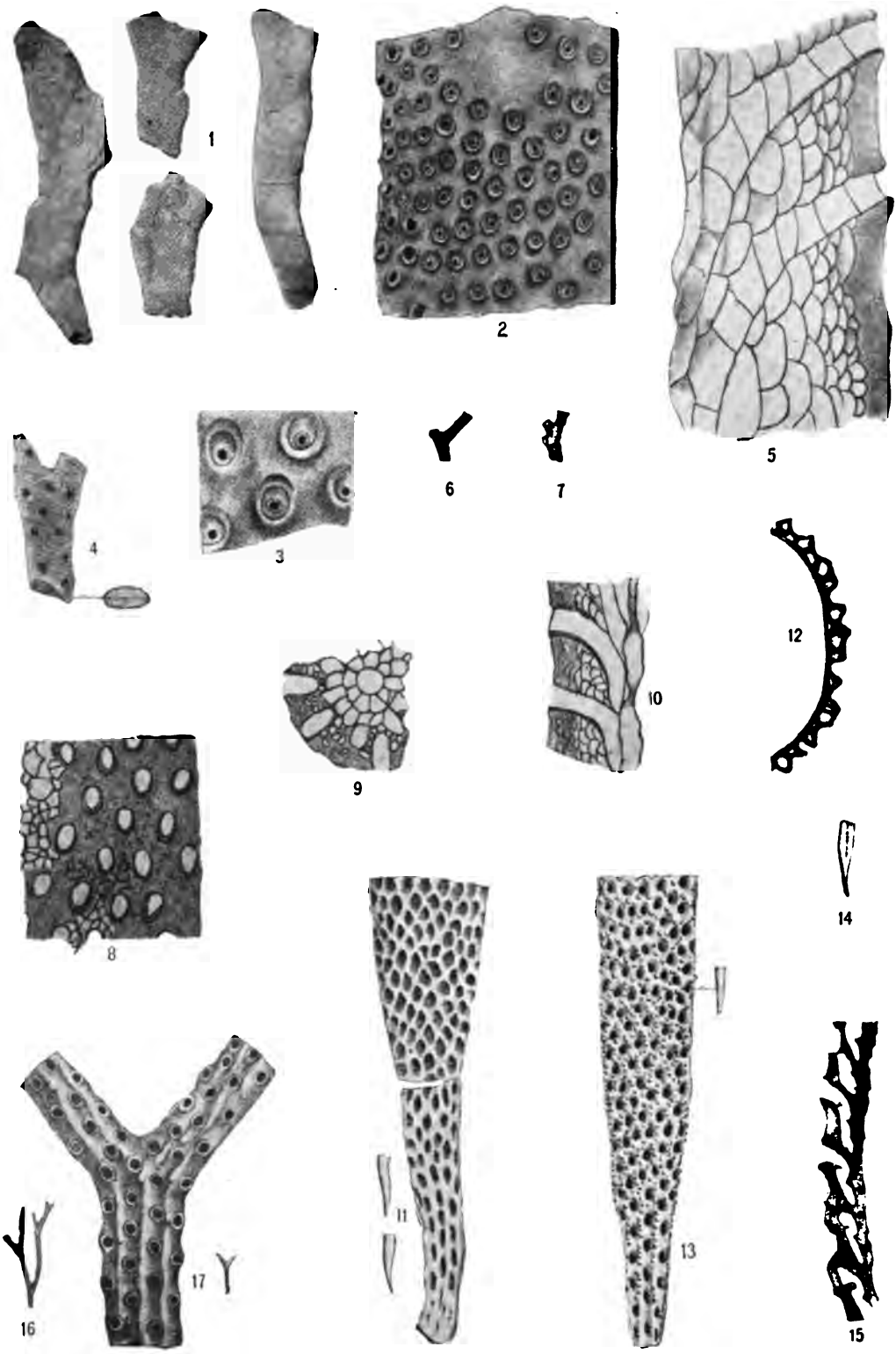

PLATE 11.
Bryozoa Glen Dean limestone, Gasper oolite and Ste. Genevieve limestone.

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